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Investigating Late Woodland-Period Aquatic Catchments through Freshwater Mussel Assemblage Composition

Sarah K. Gilleland

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Investigating Late Woodland-Period aquatic catchments through freshwater mussel
assemblage composition.

By

Sarah Gilleland

A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Arts
in Applied Anthropology
in the Department of Anthropology and Middle Eastern Cultures

Mississippi State, Mississippi

August 2016

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Sarah Gilleland
2016

Investigating Late Woodland-Period aquatic catchments through freshwater mussel
assemblage composition.

By

Sarah Gilleland

Approved:

Evan Peacock
(Major Professor)

Janet E. Rafferty
(Committee Member)

Darcy Shane Miller
(Committee Member)

David M. Hoffman
(Graduate Coordinator)

Rick Travis
Interim Dean
College of Arts & Sciences

Name: Sarah Gilleland

Date of Degree: August 12, 2016

Institution: Mississippi State University

Major Field: Applied Anthropology

Major Professor: Evan Peacock

Title of Study: Investigating Late Woodland-Period aquatic catchments through freshwater mussel assemblage composition.

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Candidate for Degree of Master of Arts

During the Late Woodland Period in the American Southeast, the amount of space that any individual group could exploit began to shrink, due to the presence of other groups on the landscape. Resource expansion occurred to augment food supplies, resulting in increased exploitation of mussel beds. Because mussels can be extremely sensitive to the characteristics of the waterways they live in, the specific habitat requirements of these animals can be used to reconstruct the environments they were recovered from. In this thesis I use freshwater mussel assemblages to reconstruct hypothetical aquatic catchments and map them onto modern rivers in the Yazoo River Basin and the Tombigbee River Basin. These are used to test ethnographic models of exploited space. I also use detrended correspondence analysis to test if sites exist in mathematical space like they do in physical space along the Yazoo River basin, as observed in the Tombigbee River basin.

DEDICATION

This thesis is dedicated to all of the people who have more faith in me than I do in myself. Thank you all for your support and encouragement over my lifetime; I would not have gotten this far without you.

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CHAPTER I

INTRODUCTION AND BACKGROUND

As population density increased in the Southeastern United States during the Late Woodland period, groups could hypothetically only exploit certain areas, being constrained by coming into contact with other groups using resources in adjacent areas (Freeman and Anderies 2015; Milner et al. 2013; Rosenberg 1998). Relative frequencies of freshwater mussels recovered from sites potentially can show the areal extent over which people at a given site were exploiting waterways, as the composition of mussels within a drainage changes along the extent of a stream and with the order of the stream (Atkinson 2012; Peacock et al. 2010). Peacock (2002) plotted mussel assemblage compositions from a number of sites using detrended correspondence analysis (DCA), which showed clinal changes between sites along the Tombigbee River and its tributaries. When plotted in an ordination diagram, the sites were observed to occur in mathematical space in the same spatial order they occur in the drainage, implying that shellfish were taken only in stream segments in the near vicinity of each site.

If this pattern is observed in other river systems, it could represent a new line of evidence supporting the conclusion that a site's population was exploiting only locally available resources. It is generally assumed that, in the Late Woodland Southeast, rising populations put stress on the hunter-gatherer groups, forcing a sedentary pattern of living (Anderson and Sassaman 2012; Caldwell 1958; Rafferty 1994; Steponaitis 1986)

Therefore, given that these population pressures should affect river drainages other than the Tombigbee, the same pattern identified by Peacock (2002) should be observed in Late Woodland sites in the Yazoo Basin of western Mississippi (Figure 1.1).

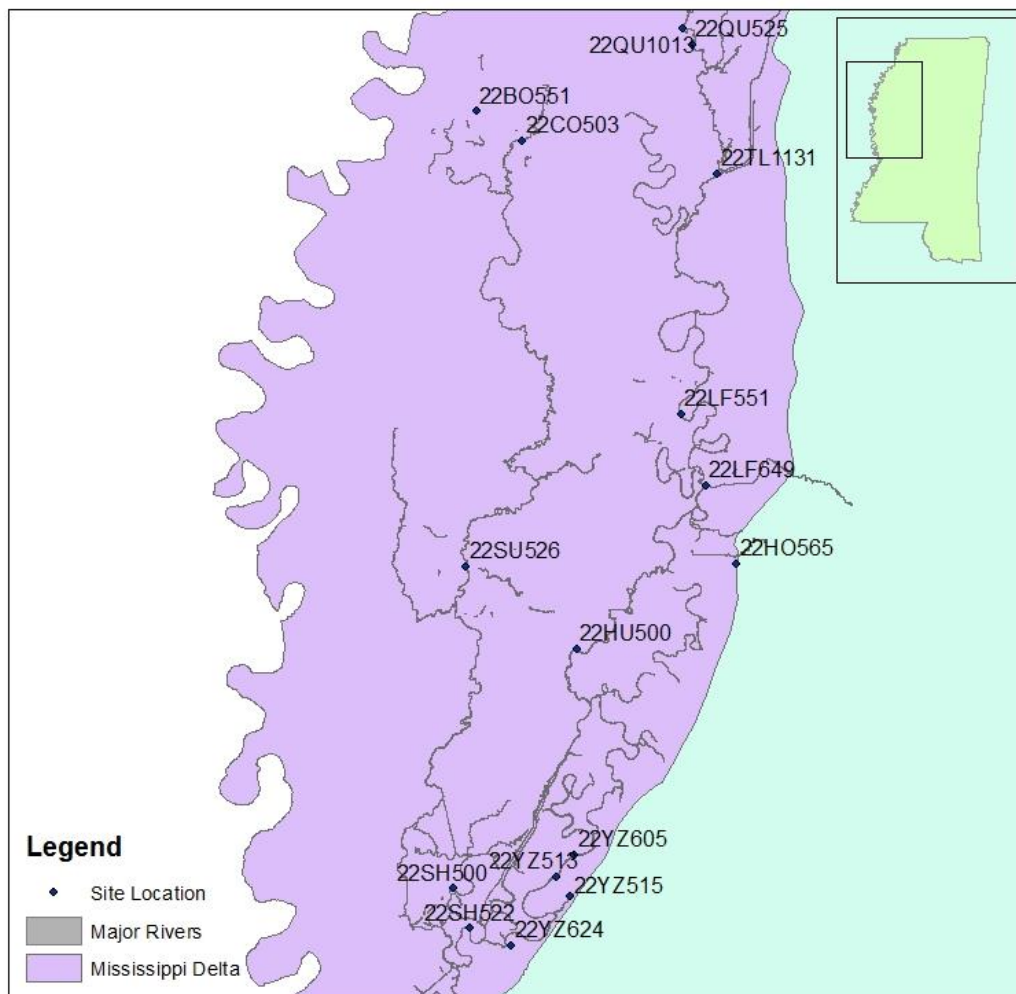


Figure 1.1 Locations of Mississippi Delta sites discussed in text.

Territoriality and the Late Woodland Period

The Woodland period is typically modeled as starting between 1200 B.C. and 700 B.C., and lasting through ca. A.D. 1000 (Anderson and Sassaman 2012; Steponaitis 1986). Steponaitis (1986: 379) notes trends that characterize the Woodland period as “(a) an increasing emphasis on the gathering and gardening of seed-bearing plants, (b) a general increase in the degree of [sedentariness], and (c) the appearance of new, elaborate forms of mortuary ritual.” The Late Woodland period in particular, starting between A.D. 500 and A.D. 600 (Anderson and Sassaman 2012; Steponaitis 1986), appears marked by changes in mortuary practices (Steponaitis 1986) and a slow breakdown of the long-distance trade networks of the Early and Middle Woodland periods (Anderson and Sassaman 2012).

The Late Woodland period is typically modeled as a liminal period between Woodland hunter-gatherers and the Mississippian chiefdoms of the American Southeast, which culminated in very sudden “Mississippianization.” This view, however, may be an oversimplified version of events. Populations of hunter-gatherers slowly rose in the millennia preceding the Late Woodland period. As populations increased, so did the demand for resources, as more people were competing for limited space and sustenance. This resulted in increased territoriality, or the defense of a home range (e.g. Rosenberg 1998). With increasing population packing on the landscape, hunter-gatherer groups became sedentary, and exploited smaller ranges.

Rosenberg’s (1998) study on the origins of agriculture in the Middle East provides a theoretical basis for approaching the formation of territories. Although it is based on Middle Eastern population studies, it provides an evolutionary approach to the

development of food production, resource intensification, and sedentariness. Rosenberg explores how the production of food mitigates the costs of abandoning a mobile settlement pattern, and posits that sedentariness comes from population pressure, making a distinction between population pressure and rising population. He concludes that sedentariness will develop where the risks of maintaining a mobile lifeway exceed the risks of more intensive development of a smaller territory space. Expanding this argument beyond the inception of sedentariness, after rising population numbers led to constriction of range space and sedentariness, this instigated faster population growth, i.e. Rosenberg's population pressure. This then selects for territoriality.

To begin, the difference between a range and a territory must be established. In this thesis, a range is considered to be the area that a given group exploits. It becomes a territory when that range is defended against other groups, or when permission must be obtained from outsiders to enter the area (Cashdan 1983; Rosenberg 1998). This distinction is important because it defines the interactions between populations; territoriality constricts the movement of the populations in the area by limiting the distance that could be traveled before encountering a hostile population (Freeman and Anderies 2015). This produces a change in the selective pressures of the area as it forces all populations to constrict movement and to defend their territories (Rosenberg 1998), causing higher death rates due to increasing warfare as the result of territory defense (Milner et al. 2013). Sedentariness arising from range constriction or territoriality could also be responsible for a rise in disease, as groups would be in sustained close contact with other group members as well as with refuse from the settlement (Clark 2010).

Another term that must be defined here is the term “catchment.” A catchment, as defined by Higgs and Vita-Finzi (1972: 28) is “the area from which a stream draws its water,” therefore an archaeological catchment may be defined as the area from which a site draws its resources. Catchment analyses are important for archaeological work because they enable archaeologists to study areas exploited by specific prehistoric human populations. While this seems similar to the definition of a range, here a range is considered the area from which a population obtains resources. A catchment is site-specific, and in this case, has also been honed to be resource-specific, as I discuss aquatic catchment for freshwater mussel resources.

Territory formation has been studied in modern hunter-gatherer populations (Ackerman and Ackerman 1973; Freeman and Anderies 2015), and has been rather broadly applied to archaeological remains from the North American Woodland period (Koldehoff and Galloy 2006; MacCord 1996; Pagoulatos 2009; Smith 2010). Many of these studies relate to the delineation of territories regionally or by culture group, and only two (MacCord 1996; Koldehoff and Galloy 2006) were done near the southeastern United States, in Virginia and the American Bottom respectively. Often these “territories” are derived from material culture, such as ceramic types and funerary objects, and the grouping measures used to place sites in “territories” overlap between the groups, leaving nothing actually diagnostic. Moreover, these qualities, such as ceramic decoration or technology, can be shown to diffuse between social groups (Wallish 2013). As these individual groups exploit different portions of the landscape, I would consider these qualities spanning multiple territories, and so rendered useless for a study of these territories.

The concept of population spacing has been applied to Mississippian chiefdoms with some degree of success (Hally 1993). Hally uses the distances between Mississippian mound sites in north Georgia with contemporary components, along with their geographical relationships to alluvial soils, to hypothesize which mound sites were related politically. He then groups the sites that he has identified as being politically related into territories, and further hypothesizes that individual territories were separated by buffer zones at least 10 km across, and commonly 20-30 km, which are an indication of defended space. However, Hally's work can only be used in areas where extensive settlement pattern data are available; it should be able to predict where other mound sites are in relation to the original sites, but his large zones are unwieldy for study. Also, given that these calculations are applied to Mississippian groups, it cannot be assumed that they can be applied to Woodland groups as well, although this method could be used to determine if a similar pattern in territory distributions exists.

Territory formation occurs when resources are limited and it is more costly to compete with other groups for resources than to defend a delineated territory (Adams 2001; Freeman and Anderies 2015; Rosenberg 1998). There are two models that have been presented for the development of territories in humans. The model of economic defensibility (MED) predicts that if resources are predictable and plentiful, then the area exploited by a group will become smaller because the group requires less area to obtain the total resources that they need. These smaller areas are more defensible against competition, leading to territory formation (Freeman and Anderies 2015). Binford (2001) applies this type of theory to his construction of a model for hunter-gatherer behavior, using division of labor as an indicator to develop predictions of group size.

The foraging effort model (FEM) predicts that sedentary groups in uncertain environments and past a certain population density threshold will form territories as groups must know where other groups are located on the landscape to make sure enough resources are obtained for all members of their group (Cashdan 1983; Freeman and Anderies 2015; Rosenberg 1998). Freeman and Anderies (2015) argue that modern hunter-gatherer populations are more in line with the FEM, but their study should be applied elsewhere with a grain of salt, as it was studying the !Ko populations in southern Africa, a relatively harsh and marginalized environment.

Despite that limitation, this model should be able to provide a testable framework for sedentary hunter-gatherer populations. If foraging effort influences human range size and territory formation, the midden features of sedentary Woodland occupations should be representative of the catchment that the site's population was exploiting. This would be shown because the population would have pooled their resources in a central location (i.e., the site) (Freeman and Anderies 2015).

While it has been argued that 20 km is the average maximum daily foraging limit (Binford 2001; Surovell 2009), it is likely erroneous to apply this limit to all hunter-gatherer groups, as the largest of these foraging radii “[occur] under special circumstances” (Binford 2001: 234) related to seasonality and climate (Binford 2001; Kelly 1995). Binford (2001) takes the approach of averaging the foraging radii of all of his samples, returning an average daily foraging radius of 8.28 km.

Kelly (1995) also relates his method of constructing foraging radii to the resources being procured. He notes that, as lesser-ranked resources are added to the diet, the same number of people can be supported by a smaller territory. Shellfish have widely

been assumed to be a second-line resource, exploited when more calorically valuable resources – such as large game – are not available (Andrus and Thompson 2012; Griffin 1967; Peacock 2002; Steponaitis 1986). Their extensive use in the Archaic and Woodland periods resulted in the creation of many shell middens across the landscape (Russo 2014; Peacock 2002).

Woodland-period shellfish use has been re-evaluated recently. Initially, it was thought that the Archaic period was the height of freshwater mussel focus, hence the term “Shell Mound Archaic” (Claasen 1992; Marquardt and Watson 1983; Moore and Thompson 2012). The assumption that this height of use occurred during the Archaic period came into question initially due to research into the caloric value of freshwater mussels, as well as the observation that some riverine sites dating to the Archaic have not produced abundant shell remains (Peacock 2002). The transition to the Woodland period was viewed as a time of subsistence diversification, with shell remains reducing in importance relative to other sources (Bird and O’Connell 2006; Byrd 1997; Caldwell 1958; Griffin 1967; Steponaitis 1986).

Peacock (2002: 447), however, has found that a “more-or-less random foray through the literature” showed freshwater molluscan remains, both bivalve and gastropod, occurring regularly in Woodland sites. These remains were also not restricted to a single type of site, being recovered from mounds, “base camps”, and permanent settlements alike. When compared to the number of valves collected from Archaic sites, once the number of valves accumulated had been corrected for time (i.e., number of valves divided by length of period), it seems that shellfish use actually peaked during the Woodland period, rather than the Archaic (Peacock 2002).

Another variable that should be considered is transportability, because “if a resource is bulky compared to its caloric value, it cannot be transported easily and this will offset its high return rate” (Kelly 1995:135). Although Kelly uses grasshoppers in his example, this idea is applicable to mussels as well. Therefore, it would be inappropriate to assume that this second-line, high effort resource would have been transported from 20 km away for its meager caloric return.

Though canoe travel would theoretically make transport of shellfish resources more viable (Andrus and Thompson 2012), the travel time to mussel beds, combined with the effort required to harvest the mussels before bringing them back to the site would truncate the distance able to be traveled in search of these resources. It is worth noting, however, that although shellfish resources have a lower caloric return than terrestrial meat, if considered for their protein content, they can provide a viable alternative to terrestrial meat when terrestrial meat is unavailable, and could provide a dietary staple of protein if supplemented with starchy cultigens to increase caloric intake (Erlandson 1988).

However, it does not seem that cultigens were a major part of the diet in the Late Woodland Mississippi Delta. This is not ubiquitous across the Late Woodland; Fritz (2008: 334) notes a “general clinal transition” between early, heavier use of native cultigens in the northern Yazoo basin and later, sporadic, or no pre-maize cultivation in the southern Yazoo basin. Gremillion (2002) also cites a relative dearth of evidence for cultivation of native seed crops in the Southeast, and indicates rapid transition to maize-based economies at the end of the first millennium A.D.

Background to the Problem

In the 1940s and 1950s, it was generally assumed that Woodland groups practiced maize agriculture, because they were observed to have burial mounds, pottery, and some form of social complexity (e.g., Griffin 1967; see Rafferty 1994). Once it was shown that these groups were not dependent on cultigens (Bender et al. 1981; Caldwell 1958; Fritz 2008; Gremillion 2002), the sedentary nature of Woodland populations also fell into question. However, the assumption of a link between agriculture and sedentariness has come under scrutiny as well. Rafferty (1994) uses several indicators at Archaic and Woodland period sites to show that the onset of sedentariness happened fairly quickly in northeast Mississippi, and many groups seem to have undergone this change relatively simultaneously (Rafferty 1994). That is not to say that this development occurred simultaneously everywhere, but simply within individual regions. Rafferty relates this pattern to increasing range compression caused by higher populations, leading to “sedentariness [that] seemingly developed in a nonagricultural context” (Rafferty 1994: 421).

The Late Woodland period in the American Southeast represents the outcome of centuries of gradual change in various aspects of settlement and subsistence patterns through the Archaic and earlier Woodland periods (Caldwell 1958; Griffin 1967; Steponaitis 1986). Continued population growth restricts movement, which resulted in increased diversification of resource exploitation (Byrd 1997; Peacock and Quitmyer in press). According to Peacock and Quitmyer (in press: 6), “changes in [faunal] population size structures frequently are coupled with the appearance or increase in use of other taxa represented in archaeofaunal assemblages.” This supports the idea that Late Woodland

groups were becoming more constrained in their ability to use the local resource base, as the appearance or increase of a wider range of faunal remains corresponds with a relative decrease in frontline resource remains such as deer, and a rise in other subsistence remains (Bird and O'Connell 2006; Byrd 1997; Peacock and Quitmyer, in press; Peacock 2002; Steponaitis 1986).

This pattern also supports the idea of a rise in competition between neighboring hunter-gatherer groups. According to the prey-choice model (PCM) of foraging efficiency, also known as the diet-breadth model, top-ranked prey will be chosen first because of the high energy return, regardless of energy expended in acquisition (Bird and O'Connell 2006). Therefore, if a group were able to use resources without constraint, the use of frontline resources would not be expected to drastically diminish. This pattern can result in overexploitation of a resource base, therefore rendering other second-line resources more necessary (Peacock and Quitmyer in press). Constriction of resource availability can also be inferred from other sources. The formation of deep shell middens during the Woodland period (Steponaitis 1986; Peacock and Quitmyer in press) can be linked theoretically to overexploitation of other locally available resources leading to an increased exploitation of second-line resources (Peacock 2002).

Although local exploitation could be linked to simply not having to go far to get food, as would be predicted in an unrestrained foraging efficiency model (Freeman and Anderies 2015), constraint can be inferred from other sources. In studies of Late Woodland period subsistence in the Tombigbee River Valley, not only does evidence for traumatic injury increase into the end of the first millennium A.D. (Blitz 1993; Milner et al. 2013; Peacock and Quitmyer in press), but the evidence from the mussel remains

shows that people were collecting and eating very small mussels (small species, and juveniles of all species) (Parmalee and Bogan 1986; Peacock 2002), expending more effort locally instead of expending that effort to forage farther. Diet breadth also expanded, with Late Woodland populations regularly eating a wider variety of species than their predecessors (Byrd 1994; Peacock and Quitmyer in press). These lines of evidence show that populations were essentially eating everything they could get their hands on, which, coupled with rising violence and skeletal markers of nutritional stress, points to stress from population pressure.

Though Peacock's (2002) conclusion of local collection was based on a DCA ordination of mussel assemblages, with supporting evidence from other indicators of population stress, the mussel assemblage datasets should also be able to show habitat data. The relative abundance of mussel species at a site can be indicative of catchment area, because different mussels have different habitat preferences; i.e., habitat data can be used to assess the catchment (and therefore the range exploited) for aquatic resources. If the catchments identified only show exploitation of the immediate vicinity, this could be used as an independent line of evidence for restricted movement.

To test this, I use a spreadsheet-based program called UNIO (Warren 1991) that uses either mussel presence, number of identified specimens present (NISP), or minimum number of individuals (MNI) of mussels to derive specific habitat characteristics. These consist of water-body type, water depth, current velocity, and substrate composition. Habitats can be plotted on maps centered on the sites; the extent of these extrapolated habitat areas should be interpretable as an exploited range. In the absence of a marked environmental boundary, overlap between habitats is likely to occur, as mussels are

distributed clinally in waterways (Atkinson 2012), so while it may not be possible to delineate an explicitly bounded hypothetical territory space, the method should provide an idea of the size of aquatic catchments.

I will be focusing on sites located in the Yazoo River Basin of western Mississippi, commonly known as the Mississippi Delta. This is the largest basin within the Lower Mississippi Valley, defined by Saucier (1994:22) as “that part of the Mississippi River system of the United States that lies between the latitude of Cape Girardeau and the Gulf of Mexico.” The Yazoo Basin covers about 7,600 sq. miles from Memphis, Tennessee to Vicksburg, Mississippi. The basin’s eastern boundary is the upland bluffs that separate the Mississippi alluvial valley from coastal plain deposits, and it is bounded on the west by the modern flow of the Mississippi River. The basin mostly consists of Holocene-age meander belts and backswamps, with about 5% made up of earlier glacial outwash deposits.

I will also be applying the UNIO program to the assemblages used by Peacock (2002) to make his initial statements about the Tombigbee River Drainage. This will show that these methods can be applied to multiple types of river drainages rather than being biased towards a single geographical location. In the interest of further methodological comparison, I will also be applying DCA to the assemblages from the Yazoo Basin to evaluate the ability of DCA to highlight patterns that are archaeologically relevant.

CHAPTER II

METHODS

Background to the Methods

Use of Shells in Archaeological Research

There are many ways to use shell remains in archaeology, particularly in paleoenvironmental studies. Shells tend to approximate chemical equilibrium with their environments because shellfish precipitate carbonates from the water they live in to form their shells (McConnaughey and Gillikin 2008; Peacock and Seltzer 2009; Peacock et al. 2012). This means that the shells of mollusks record environmental information in their growth rings as they age. This is possible because oxygen isotope ratios in water are correlated with ambient air temperature (Quitmyer et al. 1997). As mollusks use the water to precipitate their shells, the oxygen isotope ratio gets preserved in the growth layers of the shell (Quitmyer et al. 1997). This makes it possible to infer climate due to isotope ratios, which also can be used to show seasonality (Quitmyer et al. 1997). While this method can be a powerful tool, it can be limited by the species chosen for study. Large, fast-growing species may provide sub-monthly resolution when sampled, but smaller, slower-growing species may only be able to produce sub-yearly resolution when sampled at the same intervals (Mannino et al. 2003).

Chemical composition of mollusk remains can also be used to infer the source of the remains. As water flows through a drainage, it passes through different geological

areas, making different segments of a given water body chemically different from other segments (Peacock et al. 2012). Therefore, the chemical makeup of mussel shells from different sections of water bodies will be chemically distinct, due again to mollusks growing their shells from the water in which they live (Peacock et al. 2010). Using this information, archaeological mollusk remains can be compared to each other to determine the source of shell or shell-bearing artifacts from the chemical composition of shells.

Shell morphology is another way in which the source of mollusk remains can be determined. Both shell size and sculpture tend to vary within a species between upstream and downstream populations (Peacock and Seltzer 2009; Peacock et al. 2012; Zieritz et al. 2010). In some cases, this variation is so extreme that the upstream and downstream phenotypes have been classified as separate subspecies, e.g. *Lampsilis straminea straminea* (upstream) and *Lampsilis straminea claibornensis* (downstream) (Peacock et al. 2012). Upstream phenotypes tend to be laterally slimmer than the more obese downstream phenotypes, with fewer pustules (Peacock and Seltzer 2009; Peacock et al. 2012). Therefore, recovery of a downstream variant from a site with predominantly upstream phenotypes, or vice versa, may indicate that the abnormal shell is an import. This characterization must be used with caution; Peacock et al. (2012) chemically sourced a Mississippian-period shell spoon whose morphology prompted the hypothesis that it was a nonlocal import. However, trace element analysis showed that the spoon grouped with other local shells, rather than supporting the hypothesis that it had been transported to the site from a distant source.

This thesis will focus on a more traditional way to employ archaeological shell remains: habitat reconstruction. As discussed above, shell data can contribute to our

understanding of the prehistoric environment in many ways. In relation to subsistence, the inclusion of shells contributes to the catchment analysis of a site.

By using known habitat requirements for the species represented in the assemblage, mussels can be used as a proxy to determine the habitat characteristics of these catchments in prehistoric times (Peacock and Seltzer 2012; Warren 1991). This information can then be used to map the hypothetical extent of these catchments on the modern landscape (see Figure 2.1). Significant changes between strata at a site can also provide information about how a waterway may have changed over time (Peacock and Seltzer 2012). Studies using mussel habitat requirements have tended to be qualitative due to the variability in tolerance of environmental conditions between mussel species (Peacock and Seltzer 2012); however, Warren (1991) has developed a quantitative method of extrapolating habitat data from mussel species.

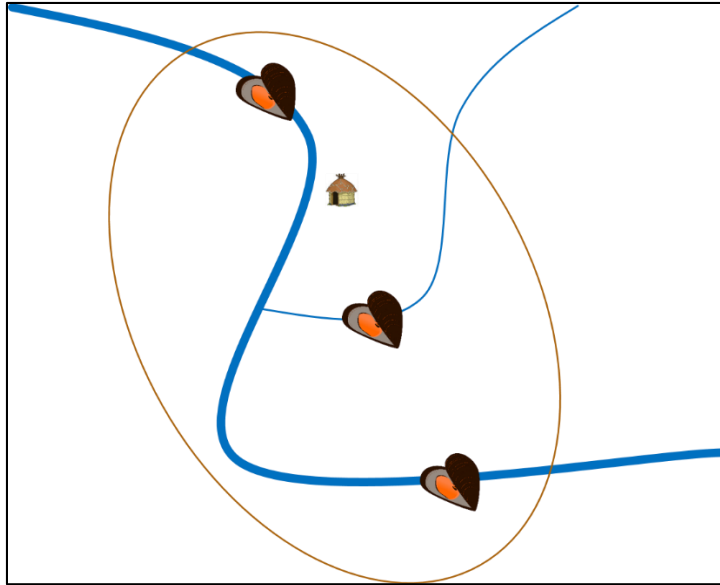


Figure 2.1 Example of the delineation of a hypothetical catchment on the landscape.

Blue lines shown represent rivers, with mussel images as mussel beds distributed in the rivers around the central site, shown as house image. Hypothetical catchment is then shown in brown.

The UNIO Program

Warren (1991) recognized the need for a way to use mussel data quantitatively to look at paleoenvironmental conditions, since mussels tend to be well-preserved at archaeological sites as they are relatively robust in structure. This means that they can be more useful environmental indicators than other indirect sources previously used for paleoenvironmental modeling, such as pollen, because shells do not always degrade in Southeastern environments (Peacock et al. 2012).

Warren's (1991) quantitative approach is based on the capacity of various mussels to tolerate different ranges of conditions in four specific characteristics: water-body type, water depth, current velocity, and substrate composition. In general, thicker-shelled species tend to prefer areas with higher current velocity and gravelly substrate, while the

obverse is true for thinner-shelled species. The variables of stream size and water depth cannot be described so elegantly; nonetheless, stream size can best be correlated to obesity of mussels, with the more obese specimens coming from larger bodies of water. Warren (1991: 29) describes the variable of water depth thus:

“The range of suitable water depth for a species may be a response to factors that correlate with depth, rather than to depth itself...water depth covaries with light penetration, temperature, amounts of dissolved oxygen, and abundance of suspended food material.”

He also notes that water depth may correlate with reproductive ability, related to the requirement that mussels live at the proper depth to infect their specific fish hosts with glochidial larvae (Warren 1991).

The quantitative method was structured by investigating the literature pertaining to mussel habitat preferences. For each species, Warren (1991) recorded the number of references associating the mussel with a given habitat category. These results were tabulated for each category, and each species was assigned a “habitat weight” representative of its abundance in that particular category. These values are 1, 0.5, or 0, which represent a species as being relatively common, relatively uncommon but known to occur, or rare/absent, respectively (Warren 1991).

There are 32 individual habitat categories across the four habitat characteristics described above. The depth characteristic is fairly self-explanatory; it contains 16 separate categories delimited by decimeter (dm). Depths from 3 to 46 dm are separated into 15 intervals, with a 16th depth of 0 added for mussels who are recorded as living in extremely shallow water (Warren 1991). Other characteristics are not so easily described.

The water-body type category is poorly quantified. Warren (1991:28) notes that although many biologists use the same kinds of terms to describe water-body types, “there is no assurance that Baker...and Parmalee...meant exactly the same thing when they wrote that a species is characteristic of ‘small rivers.’” He cites Matteson (1959), who attached the following values to river sizes: greater than 38 m wide is a large river; 15-38 m wide is medium; 5-15 is small; anything with flowing water and smaller than 5 m wide is a creek. Warren goes on to delineate a large creek as being perennial, and a small creek as one with intermittent flow, but that contains standing water throughout the year (Warren 1991).

Current velocity is another characteristic that lacks quantification. In this instance, Warren follows Buchanan (1980), who defined the categories of velocity as: 49-64 cm/sec is swift, 24-49 cm/sec is moderate, slow is 1-24 cm/sec, and stagnant is zero. Substrate composition follows the geological scale of sediment particle-size, with 64-256 mm being cobbles, 2-64 mm being gravel, 0.06-2.0 mm being sand, and the mud category including anything smaller than 0.06 mm. While each of these categories has been briefly defined by only a few contributors, for these current purposes it is assumed that all mussel biologists have used roughly the same dimensions for reporting mussel ecology.

UNIO can operate with both qualitative (presence/absence) data and quantitative (NISP/MNI) data, making it applicable to most, if not all, of the published literature. This makes it a useful tool in the face of differentially recorded mussel surveys. While this aspect of its utility should not be understated, for this thesis I have restricted my entries to assemblages with NISP/MNI data recorded. Warren (1991: 54) notes that it is inadvisable

to attempt to compare qualitative data vs. quantitative data, as the comparison may obscure or overstate the presence of “environmentally sensitive, but subdominant, members of the local mussel population.” In this thesis, I use the UNIO program to determine the characteristics of habitats that contribute to the mussel assemblages of individual sites.

Use of NISP as an Analytical Format

Many researchers argue that MNI (Minimum Number of Individuals) is a more accurate portrayal of faunal assemblage composition than its counterpart, NISP (Number of Identified Specimens Present) (Giovas 2009; Harris et al 2015; Mason et al. 1998). However, most of the data available for my study area are published in an NISP format. Therefore, I decided to examine whether NISP data will provide an accurate representation of the aquatic habitat. In most situations, I assumed it would be fairly unlikely to encounter both halves of a single bivalve in the archaeological record. Because archaeological sites accrete horizontally as well as vertically, two halves of the same shell could enter the archaeological record in drastically different portions of the site. Combined with the relatively small-scale nature of most archaeological excavations, the odds of recovering both halves of the same animal ought to be relatively slim, but I thought the matter worth investigating.

To approach this topic, Evan Peacock gave me access to his collection of published literature on archaeomalacological research in the Mississippi River watershed. Of 74 publications surveyed, only 9 publications spanning 17 sites had data reported in both MNI and NISP format (Bogan 1987; Breitburg n.d.; Jefferies et al. 2002; Peacock n.d.; Theler 1986, 1987a, 1987b, 1990, 1991). However, these sites are scattered

throughout the Mississippi River Valley (Arkansas, Mississippi, Tennessee, and Wisconsin), so the available data should provide a general survey of the region, rather than being biased towards any one spot.

I used the counts for each format to create spreadsheets to be used with the UNIO program, described above. Because this program is an integral part of this thesis, I wanted to test the effect of the different types of counts on its output. For comparison, I have also used Mantel's test for matrix correlation. This test uses a regression analysis on matrices, and is commonly used in testing the differences between environmental factors for correlation. It computes the significance of this correlation with many permutations of the rows and columns of the input matrices (Fuentes 2007). Microsoft Excel was used to format the data for the Mantel tests.

One problem with working with the Mantel test is that you have to have a square matrix to execute it (Addinsoft 2015). Because a list of species with counts is not a square matrix, I had to figure out a way to structure the data so that they fit the necessary format. To do this, I separated the organisms into columns based on subfamily. The rows consisted of each individual species of the subfamilies. When the number of rows exceeded the number of columns, I combined species based on their habitat preferences as described in Warren's (1991) UNIO program. This should keep the comparative values consistent, because the goal is to make sure that the sensitivity of habitat data is not being lost by the use of NISP data. Once the data were structured for use in the Mantel Test, the tests were run using the Mantel test for Correlation in the XLSTAT extension of Microsoft Excel with a significance value of 0.05.

For analysis in UNIO, I entered the values for MNI and NISP in separate UNIO analysis spreadsheets for each site. Any species that were not already included in the program were removed because I did not have time to perform the research necessary to add them to the program. UNIO then used the habitat weights to calculate a total weight for the assemblage in each of the habitat categories. It then took the values in each of the four stream characteristics (stream size, stream flow, sediment type, and water depth) and created graphs displaying the percentage of the data that is explained by each of the categories within that stream characteristic.

Because these graphs can be difficult to decipher, I also took the raw percentages from each habitat category and compared the two values obtained from the MNI calculation and the NISP calculation. I calculated the ratio of the MNI percentage to the NISP percentage, because simply subtracting the percentages would not give an accurate representation of how the interpretations differed.

All of the Mantel tests returned a p-value lower than the .05 significance threshold, with most reporting a p-value of “<0.0001,” with the rest ranging from .001 to .009. The scatterplots all show a fairly regular trend with slopes approaching 2, which would be the value expected for a perfect 1 to 2 correlation from MNI to NISP.

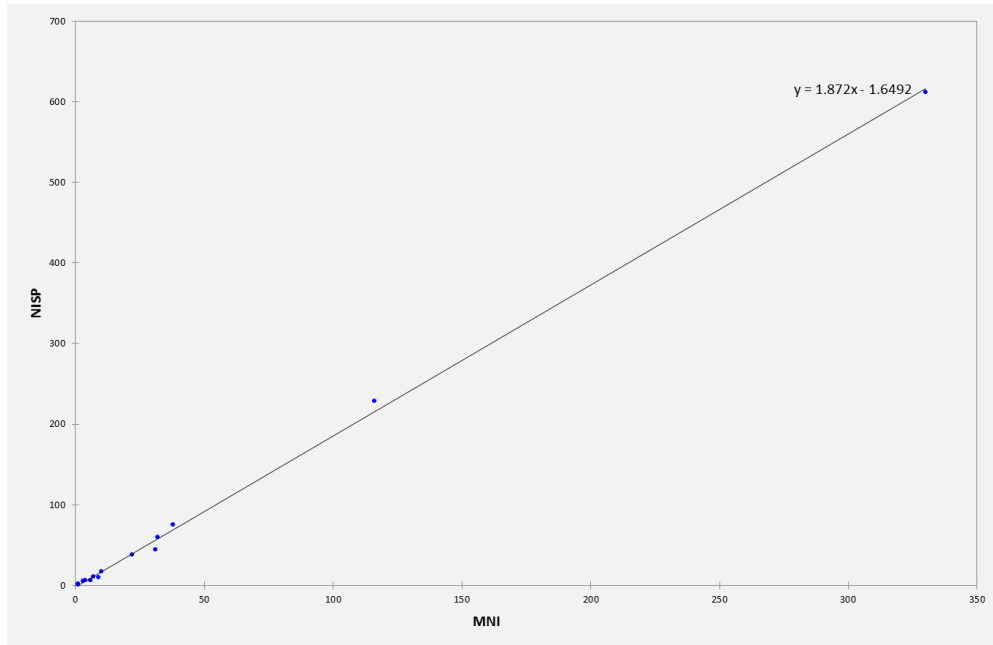


Figure 2.2 Mantel Test scatterplot of the Robinson site, 40SM4, shell data.

This scatterplot represents the data with the highest p-value, .009. This was chosen as an illustration because it is the closest to being an irregular pattern, and yet still has very close to a perfect correlation.

The graphs that comprise Figure 2.2 are from the Mill Pond site in Wisconsin.

The graphs are extremely similar for both assemblages, and even when overlaid, the two sets are practically indistinguishable at this scale. Only in one graph, of the data from the Boydell site in Arkansas, is there a slight visible change in the substrate composition graph (Figure 2.3).

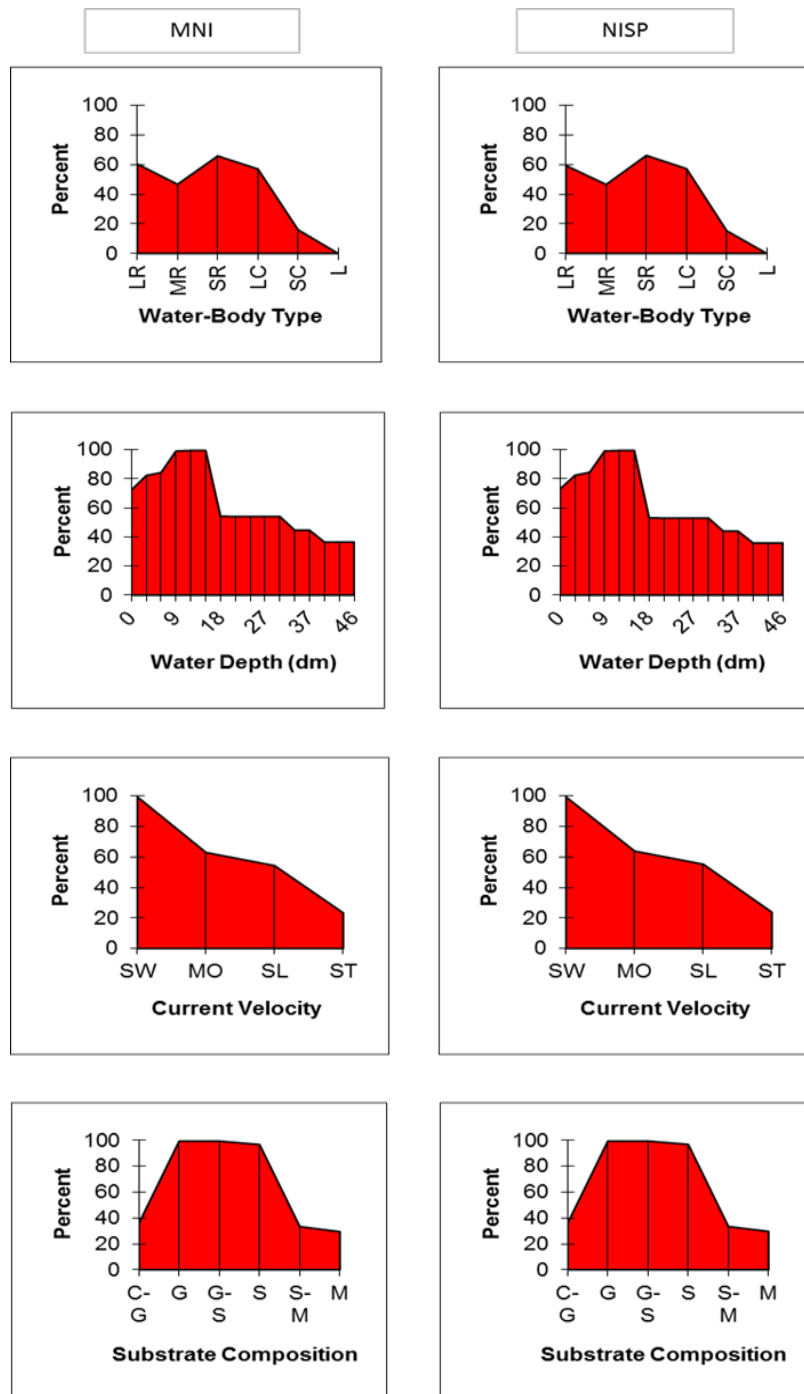


Figure 2.3 UNIO-derived graphs from the Mill Pond site, 47CR186-1.

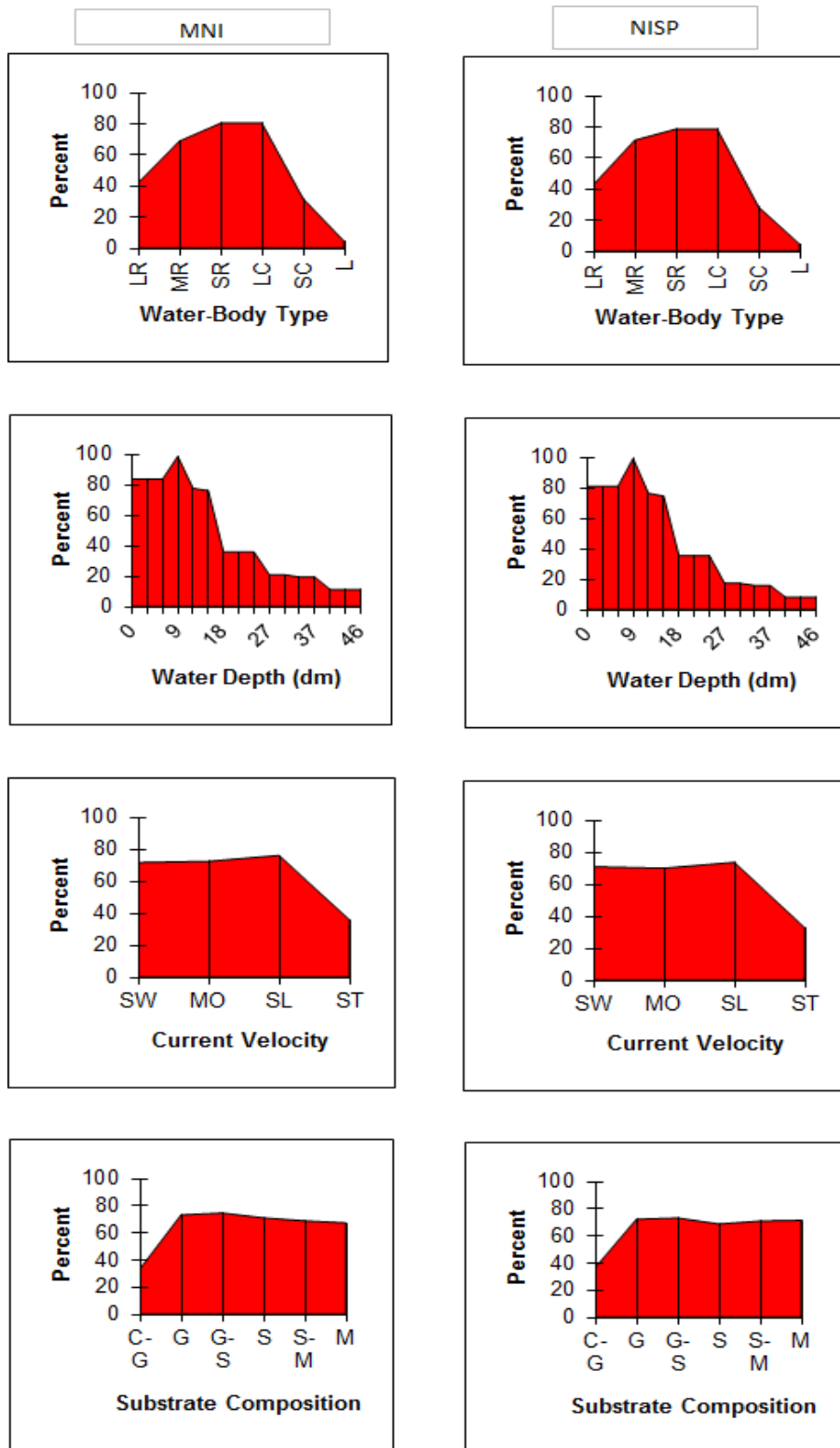


Figure 2.4 UNIO-derived graphs from the Boydell site, 3AS58.

Because the graphs were so similar, I began to compare the values the program was using to make the graphs. The values of the ratios calculated show the closeness of the percentages of each sample as they related to habitat conditions. This first graph shows the MNI to NISP ratios for all 32 categories of the Swennes site in Wisconsin.

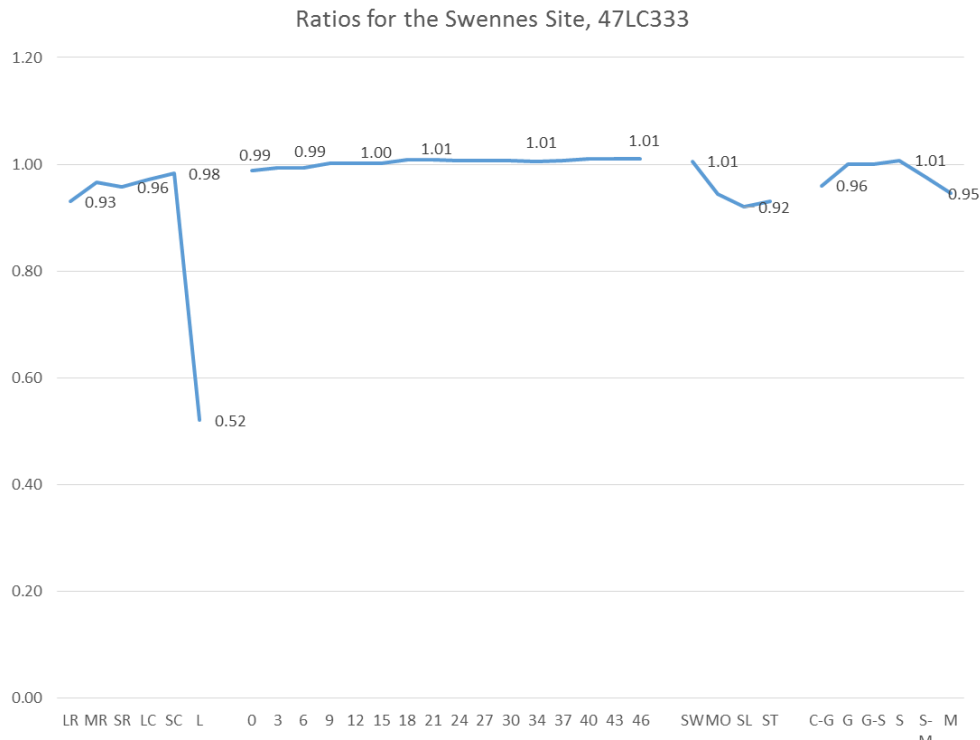


Figure 2.5 Ratios of MNI to NISP for Warren's 32 habitat characteristics.

Most of the values do not deviate far from a 1:1 ratio, with the notable exception of the stream characteristic that corresponds to the lake water body type, at 1:0.5. This happens in several cases in categories that represent an extremely low percentage of the total. It is caused by having several valves from a single side of species that are broadly tolerant in the type of habitat they can live in, in this case *Lampsilis teres*. Because *L. teres* can live in any habitat, and is the only example of a lake species from this

assemblage, this deviation is likely not relevant. However, the effects of a species being entirely represented by a single side of the animal should be noted where possible.

To show how the values of MNI and NISP relate to each other overall, I chose to average the ratios for each site and display them all at once. This also shows how the overall comparison for each site is related to the other sites I examined. Figure 1.4 shows the average ratios of each site. It looks fairly stochastic, until you take into account that the entire distribution falls between 0.94 and 1.0.

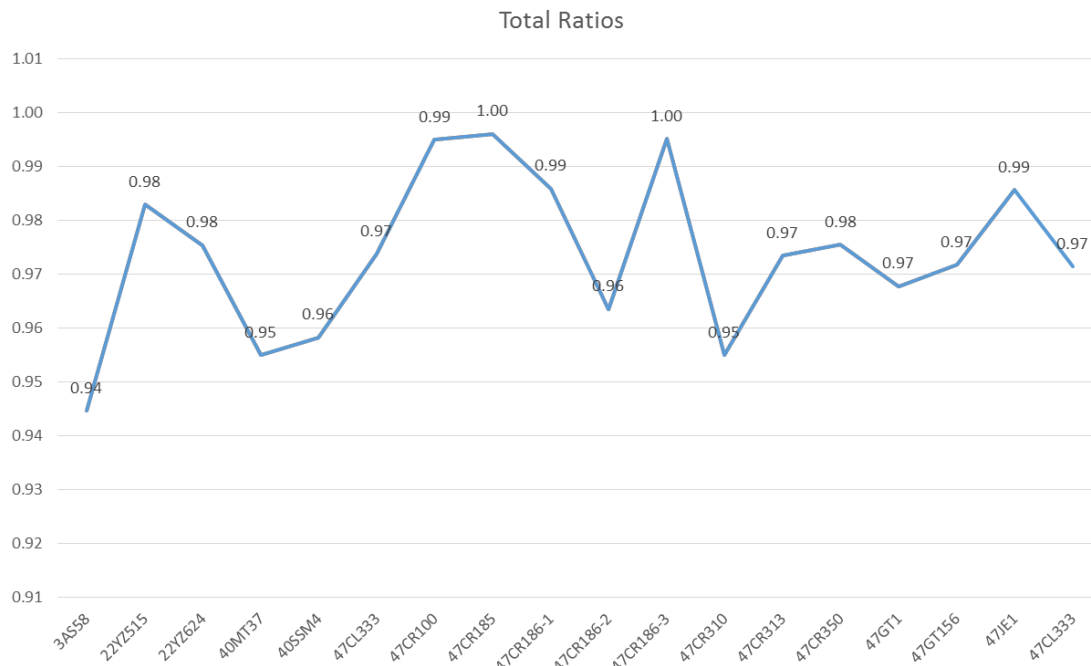


Figure 2.6 Overall ratios of MNI to NISP for each site examined.

In sum, multiple lines of evidence show that MNI and NISP are highly correlated. Both the p-values of the Mantel tests and the ratios from the UNIO tests showed very little variability between the results. There is some variability in the UNIO results, but it

is hard to pin down a pattern in the variability; several factors could be causing these discrepancies. One important thing to note, though, is that no site had a combined ratio of over 1:1. Therefore, the values produced by using MNI are consistently underestimated when using NISP. However, the discrepancies noted are not large enough to influence interpretations for environmental reconstruction using the UNIO program. Therefore, I use NISP counts for all assemblages, as this showed that using NISP counts does not adversely affect the analytical power of the assemblages.

Detrended Correspondence Analysis (DCA)

I have also examined the mussel assemblage data with detrended correspondence analysis (DCA), a type of ordination method that compares assemblages for similarities (Baxter 1994; Jackson 1993; Legendre and Birks 2012; Peacock 2002). Ordination methods are used to simplify large data sets into two or three dimensions to make the information contained therein easier to visualize, plotting individual assemblages as individual points; the points are related to each other in mathematical space based on their similarities to each other (Peacock 1998; Peacock 2002). Axes are created in such a way that the first axis accounts for as much of the variation in the point cloud as possible; a second axis is then calculated perpendicular to the first to account for as much of the remaining variability as possible, and so on (Peacock 2002).

These kinds of analysis, while informative, are usually not sufficient in their own right to explain variations in the data, which is why this is used as a supplement to the UNIO method described above (Rossi 2010). Baxter (1994:103) observes that “[ordination] is often used to display or confirm a known or suspected pattern, as opposed to discovering unknown grouping within the data.” DCA and the related

Correspondence Analysis (CA), which does not employ detrending, both rely on a chi-squared distance test to produce meaningful results (Jackson 1993). This serves to standardize the data so that species abundance is calculated relative to assemblages rather than to absolute abundance. Donald (1993: 13) also notes, however, that “this measure is susceptible to over-emphasizing rare species in sites with low taxonomic richness.” To combat this effect, the PC-ORD program (McCune and Mefford 2011) has a function that allows for the downweighting of rare species. Analyses were run both with and without this function to assess whether it was necessary.

Detrended correspondence analysis in particular was chosen over other methods of ordination due to the way it handles nonlinear data (Legendre and Birks 2012). Other methods, such as principle components analysis and correspondence analysis, assume that the relationship between the data points and the environmental gradients they represent is a standard straight line, so when presented with nonlinear data the diagram created will begin to curve, eventually creating a spiral with increasing nonlinearity (Legendre 2012; Palmer 2015; Peacock 1998). Detrended correspondence analysis removes this arching effect by recalculating the assemblage points in the second axis. This is done by dividing the first axis into segments, following which the samples within each segment are centered on a mean of zero along the second axis (Palmer 2015). This results in a decrease in the number of axes needed to produce meaningful results (Peacock 1998; Peacock 2002). The default of 26 segments is usually sufficient to reduce the arching effect, although some results can be sensitive to the number of segments used to detrend the data (Palmer 2015).

Data Acquisition

For the bulk of this project, published data reported from previous excavations were used. Peacock et al. (2011) provide mussel data for sites from several drainage basins, including the Tombigbee, Big Black, Yazoo, and Pascagoula drainages. This study focuses primarily on the Yazoo drainage.

Further fieldwork at the Spanish Fort site (22SH500) in Sharkey County, Mississippi, was completed in the summer of 2015 to augment the assemblage data from Peacock et al. (2011), and is described further in Appendix A. I was also provided with the preliminary analysis – about 90% complete (Joseph Mitchell, personal communication) – of the results of an ongoing analysis of the Rugby Hill (22YZ513) and Light Capp (22YZ605) sites in Yazoo County, Mississippi. The analysis was performed by Joseph Mitchell, Mississippi State Department of Geosciences, and is tabulated below.

During the analysis of the Spanish Fort site, another assemblage from the Belzoni site in Humphries County, Mississippi, became available. The shells from the Belzoni site which are analyzed here were collected by Dr. Robert C. Dunnell and donated to the Cobb Institute of Archaeology at Mississippi State University by his widow upon his passing away in December of 2010 (Peacock 2011). The site is located in what is now a modern graveyard; the shells from the Belzoni site were collected as surface finds after graves were dug, thus representing a site-level averaging of the available materials (Carl Lipo, personal communication). While there is little spatial control, the assemblage still produced 633 identifiable valves, which should make it an excellent candidate for comparison. There is also little evidence of collector bias in the shell samples from the

Belzoni site. The assemblage is composed not only of larger, well-preserved valves, but also includes smaller individuals, partial valves, and unidentifiable fragments.

Several sites from the Tombigbee River drainage were also included in this analysis as a comparative mechanism. The Tombigbee sites in Mississippi from Peacock et al. (2011) were augmented by mussel counts from Tombigbee sites in Alabama from Peacock (2012). Although the species composition differs between the Tombigbee and Yazoo drainages, assuming the biological mechanisms influencing mussel distribution are ubiquitous regardless of location, an analysis of range size should still be possible. At the Vaughn Mound site (22LO538), the mussels were obtained from two distinct strata, the lower dating to the Middle Archaic period and the upper dating to the Late Woodland (Peacock and Seltzer 2012). Therefore, for this analysis, only the upper Late Woodland shell counts are used. The counts are reported for each stratum in Table 2.1. Likewise, the Lubdub site shell counts are only from the Late Woodland occupation of the site, as reported in Peacock (1998).

Table 2.1 Late Woodland sites in the Yazoo River drainage, adapted from Peacock et al. (2011).

Species		Site Number											
	22TL1131	22LF551	22LF649	22HO565	22QU525	22QU1013	22BO551	22SU526	22CO503	22SH522	22YZ515	22YZ624	
<i>Actinonaias ligamentina</i>						1							
<i>Amblema plicata</i>	7	6		1	221	45		6872	107	13	71	3	
<i>Arcidens confragosus</i>					2			46	1		1	1	
<i>Cyprogenia aberti</i>								177	1		451	7	
<i>Ellipsaria lineolata</i>					3	2		5			2		
<i>Elliptio crassidens</i>											2		
<i>Elliptio dilatata</i>					139	19		617	33			7	
<i>Elliptio</i> sp.				1							2122		
<i>Fusconaia ebena</i>	21	1			169	10		3865	1	160	209	293	
<i>Fusconaia flava</i>	5	1		1	243	32		3796	136			23	
<i>Glebulula rotundata</i>							23	11					
<i>Lampsilis cardium</i>								72					
<i>Lampsilis hydana</i>				1		33		451	3				
<i>Lampsilis ovata</i>					1			8	8		6		
<i>Lampsilis siliquoidea</i>					129		3	47	27		35	9	
<i>Lampsilis teres</i>	2			22	37	14		370	24		6	4	
<i>Lampsilis</i> sp.		1							27			2	
<i>Ligumia recta</i>				3	3	3		103	1				
<i>Ligumia subrostrata</i>							6						
<i>Megalonaias nervosa</i>								172	2		11	3	
<i>Obliquaria reflexa</i>	1	6	3		66	1		2746	3		89	22	
<i>Obovaria jacksonia</i>						1					16	3	
<i>Obovaria subrotunda</i>	1				18			1	5		3	2	
<i>Obovaria unicolor</i>					14								
<i>Plectomerus dombevanus</i>	7	5		12	641	79		5102	5	2	74	26	

Table 2.1 (continued)

<i>Plethobasus cyphus</i>	4									13	1	2	5	2
<i>Pleurobema cordatum</i>														
<i>Pleurobema rubrum</i>	21	7				398	27			7115	21	64	694	65
<i>Potamilus purpuratus</i>	1					10	3			11	2			
<i>Quadrula apiculata</i>										116	2			
<i>Quadrula cylindrica</i>		2				2				56	11		3	1
<i>Quadrula metanevra</i>							1			18	1		15	
<i>Quadrula nodulata</i>	1		8	7		72	7			690	11		38	10
<i>Quadrula pustulosa</i>	17	1				274	15			5699	25		212	34
<i>Quadrula quadrula</i>			11	13		235	32	1		1503	12		133	26
<i>Quadrula verrucosa</i>	1					24	1			91	4		12	11
<i>Quadrula</i> sp.			2								1	1	1	
<i>Strophitus undulatus</i>										1	7			
<i>Toxolasma parvum</i>						12	1			17				
<i>Toxolasma texasiensis</i>							2			1				
<i>Truncilla donaciformis</i>											3			
<i>Truncilla truncata</i>						20				149	1		3	
<i>Uniomereus declivis</i>						1		3						
<i>Villosa lienosa</i>							6			5	11		9	1
<i>Villosa vibex</i>							1							
Total	89	30	55	74		2734	336	36		39946	497	242	4223	555

Table 2.2 Late Woodland Yazoo assemblages obtained from 2015 fieldwork at Spanish Fort (22SH500) (see Appendix A), Belzoni (22HU500) and Joseph Mitchell (personal communication).

Species	22YZ513	22YZ605	22SH500 0-20 cm	22SH500 >20 cm	22SH500 2014	22HU500
<i>Amblema plicata</i>	93	143	9		7	72
<i>Anodonta suborbiculata</i>			10	8	1	
<i>Arcidens confragosus</i>	6	10				10
<i>Cyrogenia aberti</i>	14	27			1	2
<i>Ellipsaria lineolata</i>		2				
<i>Elliptio dilatata</i>	48	82			1	9
<i>Fusconaia ebena</i>	1282	2033	43		138	65
<i>Fusconaia flava</i>	136	199	3		16	41
<i>Lampsilis cardium</i>	6	1				
<i>Lampsilis haryana</i>	21	26	65	53	28	22
<i>Lampsilis ovata</i>	1		20	6		4
<i>Lampsilis siliquoidea</i>	20	27	8	6	3	39
<i>Lampsilis teres</i>	38	20	53	28		46
<i>Ligumia recta</i>	19	11				
<i>Ligumia subrostrata</i>		2	26	17	36	5
<i>Meglonaia nervosa</i>	6	13				16
<i>Obliquaria reflexa</i>	160	303	2		5	2
<i>Obovaria jacksoniana</i>	60	86				
<i>Obovaria subrotunda</i>	26	50				4
<i>Obovaria unicolor</i>		6				
<i>Plectomerus dombeyanus</i>	481	707	28	3	22	45
<i>Plethobasus cyphus</i>	3	9	6		40	43
<i>Pleurobema rubrum</i>	601	1107				

Table 2.2 (continued)

<i>Potamilus purpuratus</i>	2	3					1		1
<i>Pyganodon grandis</i>			1						
<i>Quadrula apiculata</i>	8	16	1				5		
<i>Quadrula cylindrica</i>	6	16							2
<i>Quadrula metanevra</i>	2	12							
<i>Quadrula nodulata</i>	88	148	1				5		18
<i>Quadrula pustulosa</i>	153	395	2				15		52
<i>Quadrula quadrula</i>	144	231	12				9		130
<i>Quadrula verrucosa</i>	19	28							24
<i>Sirophitus undulatus</i>	2	1							
<i>Toxolasma parvum</i>	1		258	75	42				5
<i>Toxolasma texasiensis</i>			204	40	81				2
<i>Truncilla donaciformis</i>									4
<i>Truncilla truncata</i>	4	17							
<i>Villosa lienosa</i>	19	9							1

Table 2.3 Mussel data from Late Woodland sites in the Tombigbee River drainage, adapted from Peacock (1998), Peacock (2012), Peacock et al. (2011), and Peacock and Seltzer (2012).

Species	Site Number						
	22LO530	22LO538 (Upper)	22LO600	22CL527	Lubbub	1GR1X1	1GR2
<i>Amblema plicata</i>	159	7	207	61	40	23	8
<i>Ellipsaria lineolata</i>	133	4	60	5	32	49	19
<i>Elliptio arca</i>	939	1	821	192	5	55	12
<i>Elliptio arctata</i>				2			
<i>Elliptio crassidens</i>	1421	6	1184	270	22	61	54
<i>Elliptio</i> sp.	8		3		5		
<i>Epioblasma penita</i>	1991	2	397	179	9		
<i>Fusconaia cerina</i>	572	7	245	62	28	4	
<i>Fusconaia ebena</i>	475	49	218	37	403	640	559
<i>Hamiota perovalis</i>	13		8			3	
<i>Lampsilis ornata</i>	250	1	101	10	40	2	6
<i>Lampsilis straminea claibornensis</i>	26	2	6	11	13	17	5
<i>Lampsilis teres</i>	3	2				8	2
<i>Lampsilis</i> sp.	31	2	26				
<i>Leptodea fragilis</i>	1		3				
<i>Ligumia recta</i>	4	1	13		3	2	
<i>Megaloniaias nervosa</i>	1		5				
<i>Obliquaria reflexa</i>	284	6	108	19	46	30	42
<i>Obovaria jacksoniana</i>					132	32	29
<i>Obovaria</i> sp.	703	7	220	27			
<i>Plectomerus dombevanus</i>		2			1		

Table 2.3 (continued)

<i>Pleurobema decisum</i>	11473	53	3947	1571	105	15	98
<i>Pleurobema perovatum</i>	84	2	93	32			
<i>Pleurobema taitanum</i>	191	31	73				3
<i>Potamilus purpuratus</i>	10	4	4		6	5	4
<i>Quadrula apiculata</i>		1				6	4
<i>Quadrula asperata</i>	2362	50	704	369	489	484	200
<i>Quadrula metanevra</i>	41		7		27	50	18
<i>Quadrula rumphiana</i> complex	90	1	29	4	2		
<i>Quadrula stapes</i>	157	6	38	11			
<i>Quadrula verrucosa</i>	118	2	41	13	12	1	1
<i>Quadrula</i> sp.	102	1	28		10		
<i>Strophitus subvexus</i>	2		1				
<i>Toxolasma parvum</i>			4				
<i>Trucilla donaciformis</i>	35		17	1		2	
<i>Uniomereus declivis</i>							
<i>Uniomereus tetralasmus</i>							
<i>Villosa lienosa</i>			1	15	2		
<i>Villosa</i> sp.			6				
Total	21679	250	8618	2891	1432	1489	1064

Dates of Sites

Most of the sites considered here either date exclusively to the Late Woodland period or have Late Woodland period occupations (22CO503, 22SH522, 22SU526). Sites 22TL1131 and 22YZ515 have primarily Woodland period deposits, while 22LF551 produced a radiocarbon date of A.D. 1100 (Peacock et al. 2011). Because these sites may not all be exactly contemporaneous – and even were they all Late Woodland occupations, it is unlikely that they were all inhabited at the exact same time over those 400 years – the catchment delineation provided here may underestimate the catchments of the sites listed above, due to unnecessary constraint by non-contemporaneous neighbors. However, they should prove illustrative of the ability to delimit these spaces.

During the analysis of both the Spanish Fort and Belzoni sites, I conducted a preliminary ceramic analysis to help place them chronologically. I sorted pottery for temper and surface treatment, and then attempted to “type” them using Phillips’ (1970) ceramic typology. The ceramic assemblage was dominated by Late Woodland period grog-tempered sherds, mostly grog-tempered plain. Shell-tempered sherds were occasionally recovered, and two sand-tempered sherds were recovered from the Belzoni site. The results of these analyses are tabulated below.

Table 2.4 Ceramic remains from the Spanish Fort site, 22SH500.

Surface Treatment	Type	Rim	Body	Total	Percent
Grog-tempered Sherds					
Thin body incisions	Alligator Incised	0	3	3	0.55%
Zoned punctations	Avoyles Punctate	0	1	1	0.18%
None	Baytown Plain	66	434	500	92.08%
Thick body incisions	Broadline Incised	2	14	16	2.95%
Punctations	Churupa Punctate	0	3	3	0.55%
Parallel incisions around lip	Coles Creek Incised	0	1	1	0.18%
Curvilinear incisions with punctations	French Fork Incised	0	1	1	0.18%
Red-slipped	Larto Red	1	1	2	0.37%
Zoned dentate or rocker stamped	Marksville Stamped	2	8	10	1.84%
Cord-marked	Mulberry Creek Cordmarked	0	2	2	0.37%
Shell-tempered Sherds					
None	Mississippi Plain	0	3	3	0.55%
Untyped Sherds					
Possible punctations; worn	Grog-tempered	0	1	1	0.18%
Total		71	472	543	

Table 2.5 Ceramic remains from the Belzoni site, 22HU500.

Surface Treatment	Type	Rim	Body	Total	Percent
Grog-tempered Sherds					
Thin body incisions	Alligator Incised	9	22	31	0.88%
Zoned punctations	Avoyles Punctate	0	2	2	0.05%
None	Baytown Plain	438	2785	3223	91.69%
Thick body incisions	Broadline Incised	2	2	4	0.11%
Punctations	Churupa Punctate	2	1	3	0.09%
Parallel incisions around lip	Coles Creek Incised	3	0	3	0.09%
Pinched	Evansville Punctate	2	3	5	0.14%
Red-slipped	Larto Red	20	30	50	1.42%
Zoned dentate or rocker stamp	Marksville Stamped	0	7	7	0.20%
Cord-markings	Mulberry Creek Cordmarked	6	37	43	1.22%
Shell-tempered Sherds					
Cord-markings	Cahokia Cord Marked	0	1	1	0.03%
None	Mississippi Plain	11	113	124	3.52%
Pinched	Parkin Punctate	1	0	1	0.03%
Sand-tempered Sherds					
None	Alexander Plain	0	2	2	0.05%
Untyped Sherds					
Rim lug; triangular punctations on lip	Grog-tempered	1	0	1	0.03%

UNIO Methods

The spreadsheet-based nature of UNIO makes it unable to compute information for multiple sites at once. Therefore, each site had to be entered into its own unique UNIO spreadsheet. Once spreadsheets for the counts from Peacock et al. (2011), Peacock (2012), the analysis sheets from the fieldwork at Spanish Fort, and the analysis of the shell from the Belzoni site were created, I evaluated the utility of the species in UNIO Version 4 (Warren 2015). The original work that the UNIO program is based on was conducted in the Mississippi River Basin, north of the confluence of the Mississippi and

Arkansas rivers (Warren 1991). Because of this, species that primarily inhabit southern waters are not included in the original program.

The Yazoo Basin drains into the Mississippi River approximately 200 km south of the confluence of the Mississippi and Arkansas rivers. Therefore, while there are many species that are common between the two regions, the Yazoo Basin has some species that were not used when Warren wrote the UNIO program. The Tombigbee River system, in contrast, shared very few species with the Mississippi River Basin. This required me to evaluate whether excluding species not already included in the UNIO program would severely impact the results to be obtained from that assemblage. To do this, I calculated the percentage of each assemblage that was not represented in the UNIO program. If the percentage of a species not represented in the UNIO program exceeded 5%, I added it to the UNIO program. This threshold resulted in requiring all species except *Obovaria unicolor* and *Elliptio arctata* that were not listed in UNIO to be added into the program.

To add species to the UNIO program, I followed the methodology set by Warren when he created the program. This was based on acquiring as many mussel guides as I could and perusing them for the missing species. When located, the habitat ecology listed in these guides was recorded for the habitat categories previously established by Warren (1991). These were then quantified under the habitat weighting system of Warren (1991), given a 1 for recordings of “present,” 0.5 for “uncommon but known to occur,” and 0 for “rare or absent.” Once the habitat weights for new species were established, they were added into the program through Microsoft Excel. New species are listed in Table 3.3, along with their respective UNIO habitat weights. Once the initial spreadsheet for UNIO was edited to include the new species, the lines with the new species were added to the

existing spreadsheets for the site assemblages, and any gaps were filled in. I also did not add *Lampsilis radiata* to the UNIO program; it has recently been accepted that *L. radiata* is not a separate species from *Lampsilis siliquioidea* (Gerald R. Dinkins 2015, personal communication). Therefore *L. radiata* was combined with *L. siliquioidea* for UNIO analysis. It should also be noted that the *Quadrula quadrula* populations may also include *Q. fragosa*; this species has only recently begun to be identified and separated within archaeological samples (Peacock et al. under review).

Another way I manipulated UNIO to produce more workable results is through the sensitivity of the individual mussel species to their environments. The ability of some mussels to tolerate broad ranges in environmental conditions results in the UNIO program creating graphs that show the percentage of data that can be explained by any given environmental condition; it is not an exact window into the past conditions of the waterway. To attempt to refine the program to produce the most specific graphs possible, I took the spreadsheet containing all the habitat weights for each species in all 32 habitat categories and selected species which had habitat weights of 1 for up to two consecutive habitat categories in each habitat condition, meaning that only species with weight 1 occurring up to twice in any condition were selected (see Table 2.6). This created a modified UNIO program showing only those 124 species that fit this criterion. From this subset, I further selected the species that were only present in the Yazoo River basin or the Tombigbee River basin. This left me with 51 species in the specialized UNIO.

Table 2.6 Examples of sensitive (*Q. nodulata*) and non-sensitive (*F. flava*) species for Water-Body Type, Current Velocity, and Substrate Composition.

Species	Water-Body Type						Current Velocity				Substrate Composition				
	LR	MR	SR	LC	SC	L	SW	MO	SL	ST	G	GS	S	SM	M
<i>Quadrula nodulata</i>	1	0.5	0	0	0	0	0	0	1	0	0	0	0	0	1
<i>Fusconaia flava</i>	0	0	1	1	1	0	1	1	1	1	1	1	1	0.5	0.5

While many species are specific for the characteristics of Water-Body Type, Current Velocity, and Substrate composition, very few are diagnostic for the Water Depth characteristic. This is probably an artifact of the organization of the habitat categories; because the former characteristics have only between four and six divisions, more data fit into each division. As Water Depth has 16 different categories, a mussel must be incredibly specialized to be diagnostic for this characteristic. Condensing the Water Depth characteristic into fewer categories may enhance the appearance of specialization, and give a more refined idea of the relationship of the Water Depth characteristic to the other characteristics.

Table 2.7 Species added to the UNIO program, with habitat weights.

Taxon	Water-Body Type						Water Depth (dm)																
	LR	MR	SR	LC	SC	L	0	3	6	9	12	15	18	21	24	27	30	34	37	40	43	46	
<i>Elliptio arca</i>	1	1	1	1	0	0	1	1	1	1	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	
<i>Epioblasma penita</i>	1	1	1	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	
<i>Fusconaia cerina</i>	1	1	1	1	.5	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
<i>Glebulata rotundata</i>	.5	1	1	1	0	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
<i>Hamiota perovalis</i>	0	1	1	1	0	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
<i>Lampsilis hydiana</i>	1	1	1	1	0	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
<i>Lampsilis ornata</i>	1	1	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Lampsilis straminea claibornensis</i>	1	1	1	1	0	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
<i>Pleurobema decisum</i>	1	1	1	1	0	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
<i>Pleurobema marshalli</i>	1	0	0	0	0	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
<i>Pleurobema perovatium</i>	1	1	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Pleurobema taitanum</i>	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
<i>Quadrula apiculata</i>	1	1	.5	.5	.5	.5	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	
<i>Quadrula asperata</i>	0	1	1	1	0	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
<i>Quadrula rumphiana</i>	1	1	1	0	0	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
<i>Quadrula stapes</i>	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Strophitus subvexus</i>	1	1	1	1	1	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	

Weights: 1 is common; 0.5 is uncommon but known to occur; 0 is rare or absent; * is insufficient data. Habitat acronyms: In Water-Body type, LR is large river, MR is medium river, SR is small river, LC is large creek, SC is small creek, L is lake or pond. Categories for water depth are in decimeters (Warren 1991).

Table 2.7 (continued)

Taxon	Current Velocity			Substrate Composition						
	SW	MO	SL	ST	CG	G	GS	S	SM	M
<i>Elliptio arca</i>	0	.5	1	0	0	.5	1	1	1	.5
<i>Epioblasma penita</i>	1	1	0	0	0	1	1	.5	0	0
<i>Fusconaia cerina</i>	1	1	1	0	*	*	*	*	*	*
<i>Glebulula rotundata</i>	0	1	1	1	0	0	1	.5	1	.5
<i>Hamiota perovalis</i>	1	1	0	0	1	1	1	0	0	0
<i>Lampsilis hydiana</i>	0	0	1	0	0	1	1	1	1	1
<i>Lampsilis ornata</i>	0	.5	1	.5	0	1	1	1	.5	0
<i>Lampsilis straminea claubornensis</i>	0	1	1	0	*	*	*	*	*	*
<i>Pleurobema decisum</i>	0	1	1	0	0	1	1	1	0	0
<i>Pleurobema marshalli</i>	1	1	0	0	0	1	1	1	0	0
<i>Pleurobema perovatum</i>	0	1	0	0	0	.5	1	1	0	0
<i>Pleurobema taitanum</i>	.5	1	1	0	0	1	1	0	0	0
<i>Quadrula apiculata</i>	1	1	.5	.5	0	1	1	.5	.5	.5
<i>Quadrula aspirata</i>	.5	1	1	0	0	1	1	1	1	1
<i>Quadrula rumphiana</i>	1	1	0	0	0	1	1	0	0	0
<i>Quadrula stapes</i>	1	1	0	0	1	0	0	0	0	0
<i>Strophitus subvexus</i>	0	1	0	0	0	0	1	1	1	0

Weights: 1 is common; 0.5 is uncommon but known to occur; 0 is rare or absent; * is insufficient data. Habitat acronyms: In

Current Velocity: SW is swift, MO is moderate, SL is slow, ST is standing. In Substrate Composition, CG is cobble-gravel, G is gravel, GS is gravel-sand, S is sand, SM is sand-mud, M is mud (Warren 1991).

Table 2.8 Species with specific habitat requirements in the Yazoo River basin and the Tombigbee River basin.

			Sensitive for					
Taxon			Water-Body Type	Water Depth	Current Velocity	Substrate Composition		
Actinonaias	ligamentina	ligamentina			SW	MO		
Amblema	plicata	costata	SR	LC				
Arcidens	confragosus		LR	MR	SL	ST		
Cyprogenia	aberti				MO	SL		
Ellipsaria	lineolata		LR		SW	MO		
Elliptio	arca				SL			
Elliptio	crassidens		LR		SW			
Elliptio	dilatata				SW		G	GS
Epioblasma	penita				SW	MO		
Fusconaia	ebena		LR		SW			
Glebula	rotundata						SM	
Hamiota	perovalis				SW	MO		
Lampsilis	cardium		MR	SR	SW	MO		
Lampsilis	hydiana				SL			
Lampsilis	ovata		LR	MR	SW	MO		
Lampsilis	ornata				SL			
Lampsilis	siliquoidea				SL	ST		
Lampsilis	straminea	claibornensis			MO	SL		
Lampsilis	teres	teres			SL	ST	M	
Leptodea	fragilis		LR		SL	ST		
Ligumia	recta	latissima	LR	MR	SW			
Ligumia	subrostrata				SL	ST	M	
Megaloniaias	nervosa		LR		SL	ST	CG	G
Obliquaria	reflexa		LR	MR				
Obovaria	jacksonia		SR	LC	MO	SL	G	GS
Obovaria	olivaria		LR	MR	SW			
Obovaria	subrotunda		MR	SR	SW	MO		
Plectomerus	dombeyanus				MO	SL	SM	M
Plethobasus	cyphus		LR	MR		SW		
Pleurobema	decisum					MO	SL	
Pleurobema	perovatum					MO	GS	S
Pleurobema	rubrum		LR	MR		SW		
Pleurobema	taitanum					MO		G
Potamilus	alatus							SM

Table 2.8 (continued)

Potamilus	purpuratus				SL	ST	M	
Pyganodon	grandis	grandis			ST		SM	M
Quadrula	apiculata		LR	MR	SW	MO	G	GS
Quadrula	asperata				MO	SL		
Quadrula	cylindrica				SW			
Quadrula	metanevra				SW			
Quadrula	nodulata		LR				M	
Quadrula	quadrula		LR	MR				
Quadrula	rumphiana				SW	MO	G	GS
Quadrula	stapes		LR		SW	MO	CG	
Strophitus	subvexus				MO			
Strophitus	undulatus				MO	SL		
Toxolasma	parvum				SL	ST	M	
Toxolasma	texasiensis			3 6	ST		M	
Unio	declivis		SR					
Unio	tetralasmus		SC	L	ST		M	
Villosa	lienosa						SM	

Habitat acronyms follow Warren (1991). Depths are reported in decimeters. For a complete listing of sensitive species in UNIO, see Appendix B.

Once this modified version of UNIO had been created, I edited the spreadsheets for each site to include only the mussels that had been identified as sensitive species. For each site I then created a list of the habitats exploited based on the requirements of the sensitive mussels. This proved more difficult than expected. The sensitive mussels more often than not are not sensitive for all environmental characteristics. Rather, some mussels are more sensitive for one or two, rarely three, and never all four. This made the creation of discrete habitats challenging, as it required fitting information from several different mussels together for each individual habitat. I kept each list of habitats as short as possible, only adding a new kind of water body when a mussel would not fit in any of

the previously constructed habitats. This kept the assumptions for the catchment model as few as possible (Dunnell 1971).

To show the amount of information that was coming from the various habitats, I calculated the number of valves that could be identified as coming from each individual habitat. That way, if a habitat was identified that seemed to be outside the accepted range, but had very high counts included, it would be necessary to include it for any assemblage, regardless of distance to site.

However, some species still had to be excluded from contributing to the list of habitat locations, even though all species selected were diagnostic for some habitat. The species that had to be excluded were not consistent, and so did not indicate a flaw in the process of selecting sensitive species. Rather, they tended to be species on the bottom end of individual lists that were only specific for a single characteristic, and so fit multiple habitats that had already been established. As I could not reliably source them to a single habitat, I decided to omit them to prevent attributing the species count erroneously to any habitat. After habitats were identified, these were located within the buffer zones drawn around each site within ArcGIS.

GIS Methods

Once the UNIO information was complete, GIS layers were acquired to provide the necessary information indicated by UNIO. Stream size was obtained from the National Hydrography Dataset (NHD) published by the U.S. Geological Survey (USGS 2015a-f). Geodatabases for the Upper Yazoo River, Lower Yazoo River, Upper Tombigbee, Lower Tombigbee, and Big Sunflower Rivers were obtained from the USGS. Individual layers were filtered to show only perennial streams and rivers, lakes, and

swamps or marshes, which can also be habitats for mollusks that prefer stagnant water (Duobinis-Gray and Hackney 1982).

Although substrate information was not available for river segments, it should be possible to infer the substrate from other sources. Layers containing the geology of contributing aquifers were obtained from the USGS, and river conditions observed from the NHD layers were used to highlight areas where finer-grained sediments would accumulate. Because heavier sediments such as cobbles and gravel fall out first as a water body loses speed (Dincauze 2000), these sediments should occur where the water still flows quickly, where the rivers flow fairly small, straight, or in the main channels of larger, deeper rivers. Finer-grained sediments will collect where rivers eddy or meander, and in the slower shallows of larger rivers.

Current velocity proved to be even more problematic than substrate. The USGS maintains streamflow gauges in waterways across the United States, and although data by year is maintained as far back as 1921, beyond the data being produced in real-time, site-level information is not available. The data are also only relevant for each individual monitoring station. While this may be extrapolated to some of the surrounding area, doing so beyond stream confluences and other geographic changes (e.g. large meander belts, topographic changes), would not be appropriate to assign these values.

Other issues with these data come from the time of data acquisition. As the information is reported in real-time, it is affected by recent weather conditions such as rainfall and drought. Many of the monitoring stations provide information on what the station's readings are relative to "normal," but this information is not available for all stations. Only one of the five stations in the Yazoo River basin has this information,

while three of the six Tombigbee River basin monitoring stations provide it. Even where this information is available, it may be unreliable, as conditions have presumably changed in historic times; current measurements should not be taken as exact replicas of the past.

However, like substrate composition, it should be possible to extrapolate the current velocity based on the surface morphology of the river. When water is moving quickly, it is more difficult for it to change direction. Therefore, straighter sections of rivers will have faster current, while the areas where the river begins to meander will be areas where the current is moving slower (Dincauze 2000). This should not be considered an immutable law, as things like topography and obstructions can change the courses of rivers. But, because the Yazoo River basin occurs in the flat floodplain of the Mississippi River Valley, these basic principles should hold, barring human intervention.

To input the locations of the archaeological sites, a shapefile was created for them by importing the longitude and latitude of the sites through a .csv spreadsheet, as with the STPs described above. Because these would not project correctly, probably due to an error on my part in defining the latitude and longitude for ArcMap, I created a new shapefile within ArcMap and snapped points within this shapefile onto the points from the spreadsheet. The attribute table for this file was then edited to include the site names and site numbers. Once all files were in the same projected coordinate system (MSTM), I placed a 20 km buffer around each site to delineate the maximum daily foraging radius for each site (Binford 2001; Surovell 2009).

As predicted previously, these larger buffer zones proved to be unwieldy constructs. Given that the 20 km foraging radius appears to be reached only in extreme

conditions (Binford 2001; Kelly 1995; Surovell 2009), I shrank the buffer zones to 10 km. This still left some overlap in the sites that are closer together on the landscape, but overall made the proposed space to analyze for mussel catchment much more manageable. These buffer zones should provide a “baseline” for the types of waterbodies that the archaeological mussel fauna would be expected to show.

All features intersecting these buffer zones were then selected and exported into their own data frame within ArcMap. The map was then clipped to the buffer zones so that the features inside the buffer zones were the only ones shown on the map.

Detrended Correspondence Methods

The program used to perform the DCA was PC-ORD version 6.19. The counts of mussel shell for the Yazoo sites were initially entered into a single spreadsheet which had to be formatted for use with PC-ORD. I only ran a DCA on the shell remains from the Yazoo River drainage, as DCA of the sites from the Tombigbee River drainage has already been published by Peacock (2002).

Formatting for PC-ORD followed the template of entering the species by column and the individual assemblages by row. For the species columns it was necessary to abbreviate the species, as the row headers cannot exceed 8 characters. For this I took the first four letters of the genus and the first four letters of the species to generate unique headers for each species; i.e. *Amblema plicata* becomes AmbIPlic, *Quadrula quadrula* becomes QuadQuad, *Potamilus purpuratus* becomes PotaPurp, etc. To attempt to reduce the statistical noise in the test, certain difficult-to-separate species were either removed or combined: both species of *Toxolasma* were combined under the heading “Toxolasm;” *Lampsilis cardium* was folded into *Lampsilis ovata*; *Lampsilis radiata* was folded into

Lampsilis siliquoidea; and *Obovaria retusa* was deleted, as this is most likely a misidentification (Peacock et al. 2011).

Once the data were entered into a single spreadsheet, the spreadsheet was imported into the PC-ORD program as a “Main Matrix” and was ordinated with the “DCA (DECORANA)” function. The program then produced a results table giving the eigenvalues for each axis and the individual values for each species. The results could then be graphed by site, species, or both. It quickly became clear that using all the sites in the Mississippi Delta region would not allow for drainage-level patterns to be evident, so I reconfigured the data into two separate spreadsheets, one for the Yazoo River sites and one for the Big Sunflower River sites. This was a much better scale for drainage-level resolution. I had to remove sites in each drainage due to small sample size: 22BO551 and 22HO565 from the Big Sunflower, having 36 valves and 58 valves respectively; 22LF649, 22LF551 and 22TL1131 from the Yazoo, with 53 valves, 27 valves, and 69 valves respectively, appeared to be overly affecting the results.

CHAPTER III

RESULTS

Combining UNIO and GIS

As the results were obtained using the modified UNIO program to identify habitats as specifically as possible, it should be noted that the total counts reported only represent the total number of valves that were from species identified as being sensitive for one or more variables within the UNIO program. As the type of waterbody is frequently an unknown variable, if the type is simply described as “a waterbody,” then the type is unknown. Specific depth is only provided where known. Otherwise unknown variables will be stated as “unknown [variable].”

It was not possible to reliably quantify the characteristics of substrate composition and water velocity because of the mismatch in scale between the data that were available for these characteristics. Therefore, when constructing habitats using the UNIO information, I relied the most on the waterbody type characteristic. In most cases this proved adequate to the task. Where this information was unavailable or there were several types of a given waterbody type present, such as two large river habitats with different velocity and/or substrate, I turned to current velocity as the second-most observable characteristic due to surface morphology, as described above.

In most cases, it was possible to locate the habitats described by UNIO in the modern landscape. Some landscapes were obscured due to human interference, and in

others the rivers themselves appear to have changed in characteristic over the intervening millennia between the conditions identified and the current landscape being observed. Nonetheless, I was able to use the method outlined above to create hypothetical, non-overlapping catchment areas around each site, constructed based on the assumption that length of stream is directly proportional to number of mussels obtained.

Besides the hypothesized catchments described below, the results of the UNIO analysis provided support for previous research showing the constriction of foraging territory in the Late Woodland period (Bird and O'Connell 2006; Byrd 1997; Griffin 1967; Peacock 2002; Peacock and Quitmyer in press; Steponaitis 1986). This support is shown in comparisons between sites that are located close together, within the 10 km buffers set up in ArcMap. If these sites represented the movement of camps, it would be reasonable to expect that some of the old collection grounds would still be in use. However, when examined, there is no overlap in the fauna collected in these closely located sites, beyond what would be expected if they are located along the same waterway. This enables the rejection of the hypothesis that the catchment area is shared.

Yazoo Sites

Table 3.1 Habitats from Acree Place (22BO551)

Habitat Type	Percentage
Small river, slow to stagnant current, sand-mud substrate	80.5%
Large river, slow to stagnant current, mud substrate.	19.5%

Table 3.2 Habitats from Oliver Mounds (22CO503)

Habitat Type	Percentage
Small river, slow current, sand-mud substrate	53.5%
Large river, swift current, gravel or gravel-sand substrate	28.3%
Large river, slow current, mud substrate	17.1%
Large river, slow to stagnant current, gravel substrate	1.0%

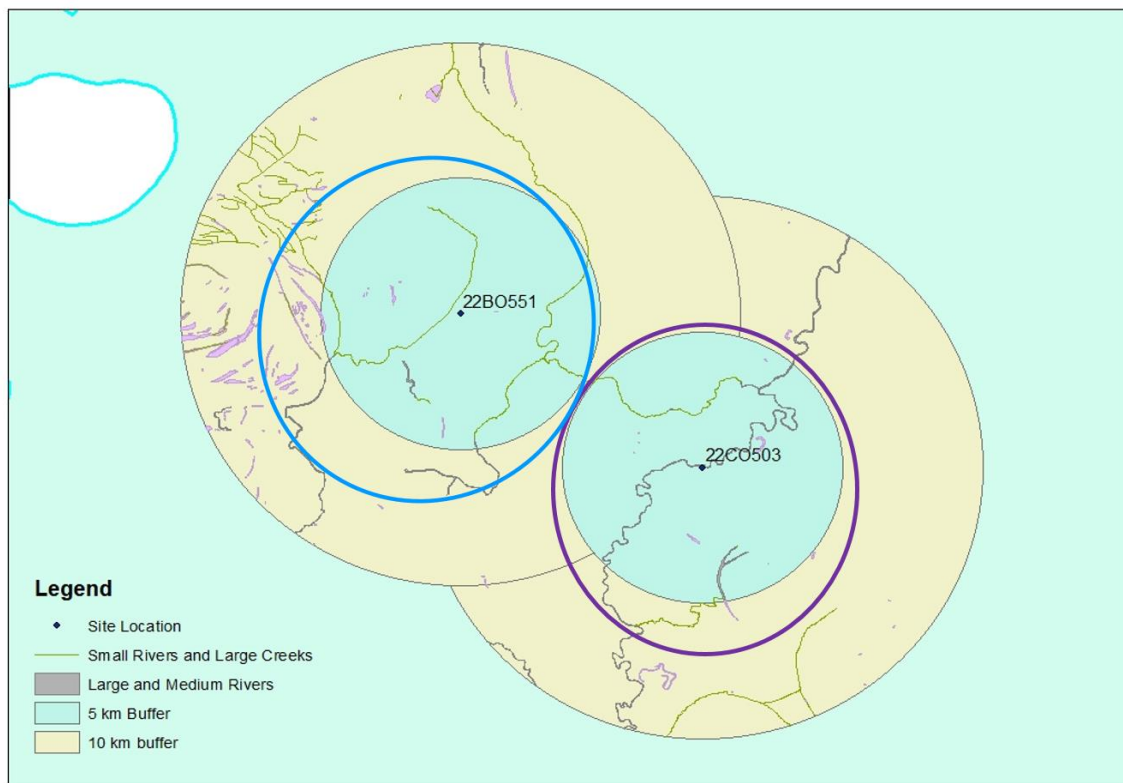


Figure 3.1 UNIO-delineated riverine catchment space for Acree Place (22BO551) and Oliver Mounds (22CO503).

Catchment for Acree Place is demarcated in blue, and Oliver Mounds is outlined in purple.

The Acree Place and Oliver Mounds sites are an excellent example of this phenomenon. Located only a little over 10 km apart on the landscape, the fauna

recovered from the two sites are very different. The inhabitants of Acree Place drew the bulk of their shell from small rivers; therefore, even though there are large rivers within the 10 km buffer zone, these were likely not able to be heavily exploited. However, about 20% of the shell is from a large river habitat, so they could not be completely limited to the 5 km buffer, which has almost no large rivers. The catchment must then expand outside of the 5 km buffer to obtain the large river species. As the large rivers on the southwest are the closest to the site, these would be the most likely to provide for this site. It is also possible that larger rivers existed northwest of the site, as during the Late Holocene the Mississippi River ran much closer to Acree Place than it does now (Saucier 1994).

Conversely, Oliver Mounds is split nearly half-and-half between large river and small river species, though it is surrounded predominantly in the 5 km buffer by large and medium rivers. Although some parts of the features within the Large and Medium River layer are capable of being classified as small rivers due to the width of the features, these areas are not generally extensive, so the small river species must be coming from elsewhere. Extending the territory south increases the amount of small river habitats included in the catchment. In fact, the area delineated in Figure 4.1 may be conservative, and it is possible that the small rivers farther to the southwest should be incorporated as well.

Table 3.3 Habitats from Shady Grove (22QU525)

Habitat Type	Percentage
Small river or large creek, slow current, sand-mud substrate	37.7%
Large river, swift current, gravel or gravel-sand substrate	30.5%
Large river, slow current, mud substrate	15.9%
Small river, slow current, gravel-sand or sand substrate	15.1%
Medium river or small river, swift to moderate current, unknown substrate	0.8%

Although the Shady Grove site is situated on a fairly large river, measuring about 43 m wide at the site, the bulk of the shells from this assemblage (52.8%) come from a small river habitat. This necessarily means that the catchment space must be extended beyond the 5 km buffer zone to the nearest small river, at minimum 5.8 km away. Exploiting the large river that must be traversed on the way to the small river most likely accounts for the large river species in the assemblage. The medium river habitat contributes only 0.8% to the assemblage, which means the small part of the medium river connecting the large and small rivers is probably the extent of this waterway being exploited. The space outlined in Figure 4.2 most likely includes more of the medium river than was actually exploited, due to the constraints of working with ellipsoids to outline projected catchments.

Table 3.4 Habitats from Louise Henry (22QU1013)

Habitat Type	Percentage
Waterway, moderate to slow current, sand-mud substrate	36.2%
Large river, slow current, mud substrate	24.3%
Small river, unknown current, gravel or gravel-sand	19.6%
Large river, swift current, gravel to sand substrate	19.1%
Waterway, 30-60 cm deep, stagnant water, mud substrate	0.9%

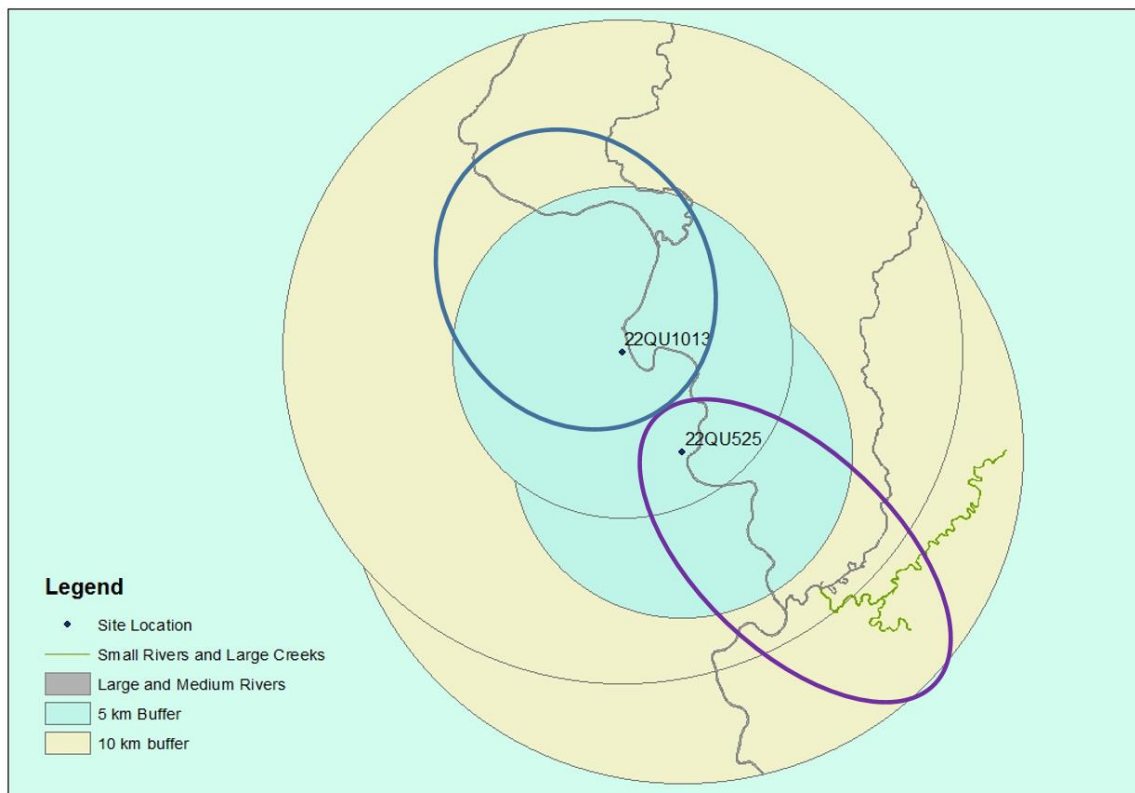


Figure 3.2 UNIO-delineated riverine catchment space for Shady Grove (22QU525) and Louise Henry (22QU1013).

Table 3.5 Habitats from Greg Sheely (22TL1131)

Large river, swift current, unknown substrate	72.5%
Small river, slow current, mud substrate	14.5%
Small river or large creek, swift to moderate current, unknown substrate	11.6%
Large river, slow current, mud substrate	1.4%

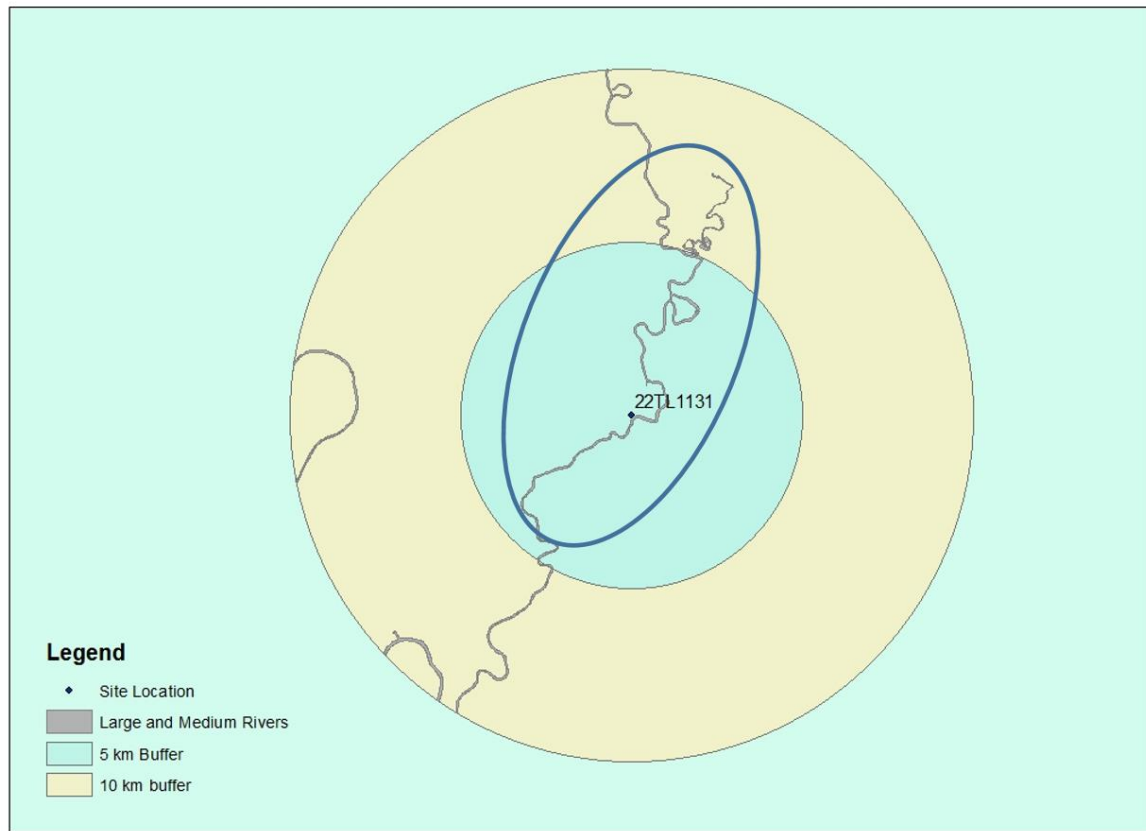


Figure 3.3 UNIO-delineated riverine catchment space for the Greg Sheely site, 22TL1131.

The Greg Sheely site catchment is more difficult to delineate, as I do not have information from surrounding sites to help narrow it down. Nonetheless, it is possible to get an idea of the catchment in standalone sites with this method. As expected, the

majority of the shells from this site come from a large river habitat. However, 26.1% of the shells came from a small river habitat, of which there are none within either the 10 km or 5 km buffers. Several possibilities exist for this disparity: the river could have changed course and character between the time these maps were created and when the site was inhabited; the mussels present could be more sensitive to other characteristics, such as substrate or water velocity; or there could be sections of the large and medium river where the river width is small enough to be considered a small river, as the medium river just outside the 5 km buffer zone is on the smaller end of medium rivers, generally between 25 and 30 m across.

The region containing the Gary #2, Palusha Creek, and French sites was complicated for multiple reasons. First, the molluscan sample size for each of these sites was very low, between 27 and 58 valves. The information provided is therefore likely to be incomplete. Second, the patterns of the aquatic habitats in the area show extensive change over time, as evidenced by oxbow lakes and defunct river channels. Other modifications appear to be human in origin. Nevertheless, I employed the UNIO patterns as best as possible in this situation.

Table 3.6 Habitats from Gary #2 (22LF551)

Habitat Type	Percentage
Small river or large creek, moderate to slow current, sand-mud or mud substrate	59.3%
Large river, swift current, gravel or gravel-sand substrate	40.7%

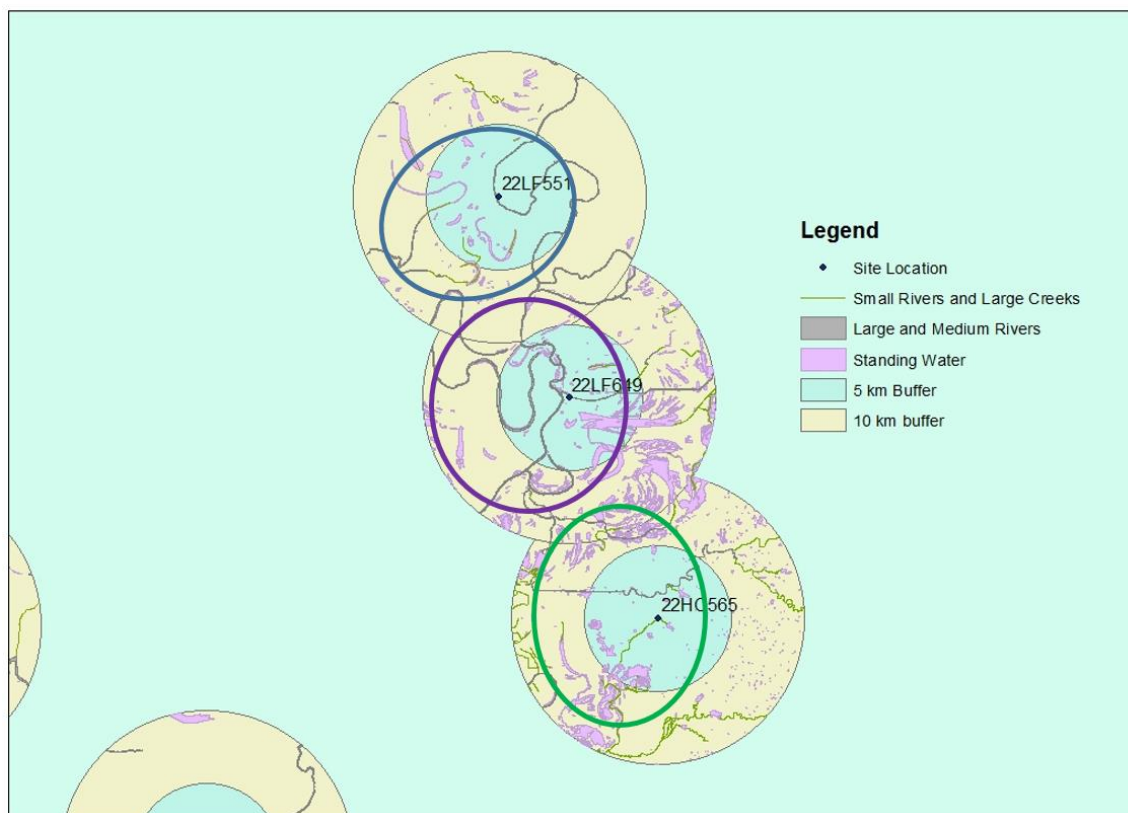


Figure 3.4 UNIO-delineated riverine catchment space for the Gary #2 (22LF551), Palusha Creek (22LF649), and French (22HO565) sites.

Catchment for Gary #2 in blue, Palusha Creek in purple, and French in green.

At the Gary #2 site, the remains were split nearly equally between small river and large river habitats. On the modern landscape, the closest waterway is a large river, but there are several old river channels that are now coded as standing water nearby. Because the waterways that connect these are coded as creeks and small rivers, these waterways should represent the ancient small river habitat that flowed near the Gary #2 site in antiquity. As most of the remains were from the small river, this portion of the landscape was expected to contribute the most, and so the delineated catchment covers more of this

space. This also encompasses several bends of the nearby large river, as 40.7% of the shell was from a large river habitat.

Table 3.7 Habitats from Palusha Creek (22LF649)

Habitat Type	Percentage
Large river, swift current, gravel to sand substrate	58.5%
Large river, slow current, mud substrate	41.5%

The remains from the Palusha Creek site were exclusive to large rivers. For this reason, I focused the catchment on the western portion of its 5 and 10 km buffers, as the large river system in this portion exhibits geographical properties that would be indicative of multiple current velocities and substrates. The meander belts would slow the river flow, increasing siltation; speed would increase in the straighter, more direct stretches, which would also lead to an increase in the sediment size particles. These two types of large river were responsible for the species that accumulated at the Palusha Creek site, making them the logical candidates for the territory of this site. However, as shown by the meander scars west of the site, along with the maps by Saucier (1994), Palusha Creek itself was once a major branch of the Mississippi River, and may have been running during this time.

Table 3.8 Habitats from French (22HO565)

Habitat Type	Percentage
Large river, slow current, mud substrate	74.1%
Waterway, moderate to slow current, sand-mud or mud substrate	20.7%
Large river, swift current, unknown substrate	5.2%

The area surrounding the French site shows the most evidence of modern human manipulation of the landscape. The meandering river north of the site very abruptly proceeds in a very straight line for nearly 6 km, north of what is now tracts of farmland, in a channel known as the “Aibacha Creek Diversion Canal” (Google 2016). Southwest of the site, oxbow lakes show where river channels once flowed. Though the site is located just outside of the deposits analyzed by Saucier (1994), the site is located along a small stretch of “undifferentiated alluvium of small streams” (Saucier 1994: plate 4). It is located on backswamp deposits, also delineated as alluvial fans. These may have been seasonally refreshed wetlands fed by the streams that still flow. Saucier (1994) also shows the modern oxbow lakes as having been relict channels of the Mississippi river, which still may have been fed at a smaller scale by the rivers that continued to run after the Mississippi changed course.

The Kinlock and Belzoni sites are shown in the same map due to their close geographical position, regardless of being located on different rivers with non-overlapping buffers. The majority of shell from the Kinlock site is from large river habitat, which is consistent with its location on a large river. The remaining variation comes from both medium and small rivers, as well as the possibility of a large creek habitat. Within the 10 km buffer of the Kinlock site are a variety of riverine habitats that

could provide the rest of these shells. The closest medium river is at the southern end of the 10 km buffer, which must be within the exploited catchment. The other habitats that are either medium/small river or small river/large creek must come from the surrounding feeder streams into the large river. However, it does not appear that much space was exploited along these feeder streams; as shown in the map, a small river abruptly widens into a larger waterbody at the eastern edge of the 5 km buffer. If these streams were being exploited farther from the main river, I would expect to see more than 62.4% of the shell coming from these large river habitats. The northern edge of the catchment was placed above the northern meander belt to account for the variation in the large river characteristics. The catchment must extend to the slower-moving waterway, as 13.3% of the shell was related to large rivers with slower current.

Table 3.9 Habitats from Kinlock (22SU526)

Habitat Type	Percentage
Large river, swift current, gravel or gravel-sand substrate	49.1%
Small river or large creek, slow to stagnant current, sand or sand-mud substrate	23.4%
Medium river, slow to stagnant current, mud substrate	18.6%
Medium river or small river, moderate current, gravel to sand substrate	8.4%
Large river, slow current, mud substrate	7.5%
Large river, slow to stagnant current, cobble or cobble-gravel substrate	5.8%

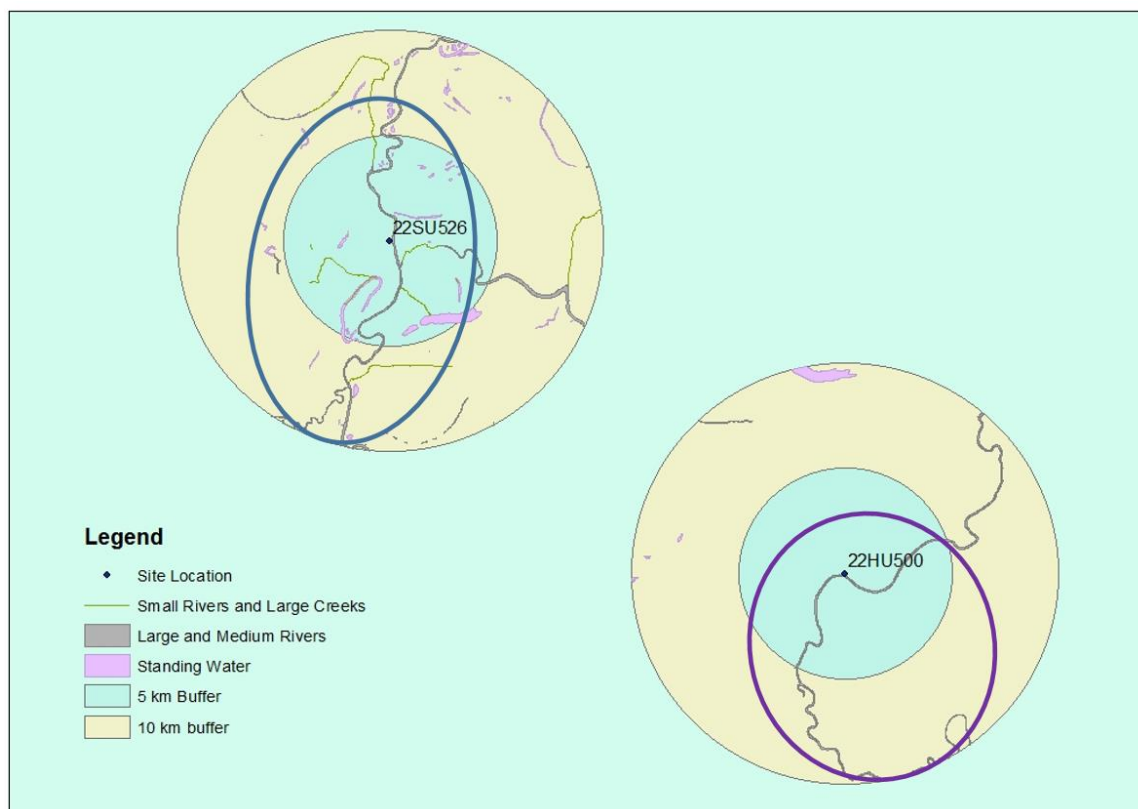


Figure 3.5 UNIO-delineated riverine catchment space for the Kinlock (22SU526) and Belzoni (22HU500) sites.

Catchment for Kinlock in blue, Belzoni in purple.

Table 3.10 Habitats from Belzoni (22HU500)

Habitat Type	Percentage
Large river, slow current, mud substrate	23.9%
Large river, swift current, gravel or gravel-sand substrate	21.8%
Waterway, slow current, mud substrate	15.2%
Small river, moderate current, unknown substrate	14.4%
Large river, slow to stagnant current, gravel substrate	2.5%

The Belzoni site contains species specific to large and small rivers, though the large river that flows immediately adjacent to the site contributes the most to the shell recovered, at 48.2% of the total. There is also 14.4% of the remains which were from a waterway of unknown size; this is most likely a meandering section of the large river with moderate current and mud substrate, bringing the total provided by the large river to 62.6%. The remaining percentage of the remains that came from a small river can be related to the small river branch on the southeastern edge of the 10 km buffer.

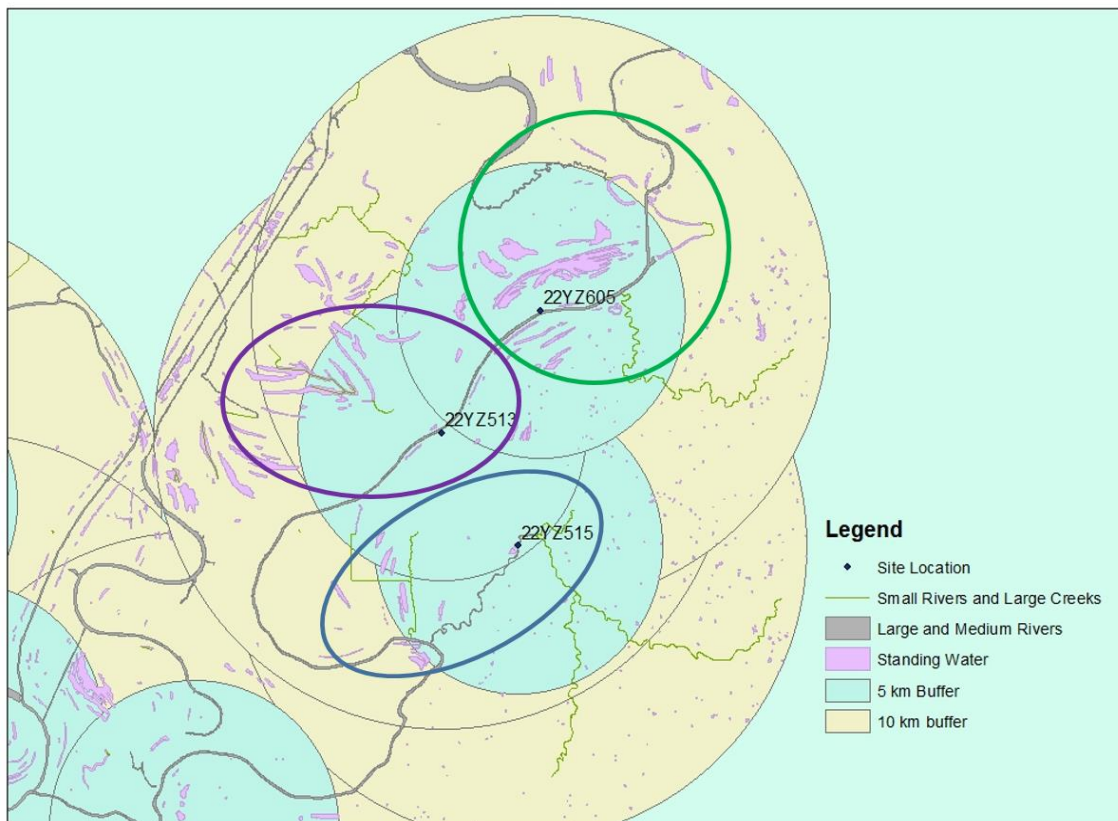


Figure 3.6 UNIO-delineated riverine catchment space for the O'Neil Creek (22YZ515), Rugby Farm (22YZ513), and Light Capp (22YZ605) sites.

Catchment for O'Neil Creek in blue, Rugby Farm in purple, and Light Capp in green. Linear features in the northeast are excluded from the analysis; they are man-made.

Table 3.11 Habitats from O’Neil Creek (22YZ515)

Habitat Type	Percentage
Large river, swift current, gravel or gravel-sand substrate	55.3%
Small river, moderate current, gravel or gravel-sand substrate	28.5%
Large river, slow current, mud substrate	9.3%
Medium river, slow current, sand-mud substrate	6.3%
Large river, slow to stagnant current, cobble-gravel or gravel substrate	0.6%

The O’Neil Creek site at first seems incongruous relative to its remains, being located on a small river but having the majority of its shell from a large river. However, when the river the site is located on is measured in ArcMap, it appears to be one that cannot accurately be quantified. Most of the river is between 12 and 15 m wide, putting it on the upper end of small rivers. However, some stretches are as narrow as 8 m, and others as wide as 27 m. Therefore, this single river is capable of sustaining species from all river types, and is therefore likely contributing some of the large river species. An examination of the oxbow lakes within the buffer also reveals that the large river this waterbody flows into was likely located farther east in antiquity than it is now, which resulted in my marking the eastern boundary closer to the site.

The Rugby Farm remains were also mostly related to the large river, and this territory probably abuts the territory for O’Neil Creek along the river. Medium river and small river habitats also contributed to the O’Neil Creek assemblage, although in its case the medium river habitat outweighed the small river, rather than vice versa. Rugby Farm has a myriad of small river habitats to the north that would have been exploitable in antiquity; the old river tracks show that these small rivers once connected to the large

main channel. The medium river habitat may be smaller sections of the large river, but based on the differences in substrate, this medium river is probably one that created some of the defunct river channels, and no longer exists.

Table 3.12 Habitats from Rugby Farm (22YZ513)

Habitat Type	Percentage
Large river, swift current, gravel or gravel-sand	66.6%
Medium river, slow current, sand-mud substrate	27.4%
Small river, swift current, gravel or gravel-sand substrate	5.8%
Large river, slow to stagnant current, cobble-gravel or gravel substrate	0.2%

The Light Capp site again draws the majority of its species from the large river on which it is situated. However, this site shows evidence of collection to the north, away from the catchments delineated at the other sites. At the Light Capp site there is some evidence for the possibility of the exploitation of a lake habitat, though the habitat could also be a creek. The mussels responsible (*Ligumia subrostrata* and *Villosa lienosa*) are more sensitive to current velocity and substrate than waterbody type. In the absence of other creek species, and given the presence of oxbow lakes on the landscape, it is therefore more probable that this is a lake exploitation; however, the argument can also be made in the reverse, as there are no other lake species either. A medium river exists in the northern portion of the 5 km buffer, providing the species that are medium river-specific, and a small river feeds into the main large river just upstream of the site. While the large river has been modified by humans, north of the site, as evidenced by the

straight north-south channel cutting off a meander upstream, the meander was preserved as an oxbow lake, and so is included in the catchment delineation.

Table 3.13 Habitats from Light Capp (22YZ605)

Habitat Type	Percentage
Large river, swift current, gravel or gravel-sand substrate	68.1%
Medium river, slow current, mud substrate	24.2%
Small river, swift current, gravel or gravel-sand substrate	6.6%
Large river, slow to stagnant current, gravel substrate	0.8%
Large creek to lake, slow to stagnant water, sand-mud substrate	0.2%

The Spanish Fort site was split into two separate analyses due to the diversity in the remains. The top zones of the STPs contained robust species such as *Fusconaia* sp. and *Quadrula* sp. The zones below these contained relatively higher proportions of gracile species (*Ligumia* sp., *Lampsilis* sp., *Toxolasma* sp.), and the robust species were notably absent. Several hypotheses exist to explain this variability; it may be due to a sampling error due to insufficient survey, or a shift in the characteristics of the waterways being exploited (see discussion in Appendix A). Nonetheless, these two zones are examined separately until it can be determined whether they are representative of a single environment.

Shells in the upper zone were mostly obtained from large river habitats. This is consistent with the current form of the river. A large creek habitat and an unknown waterway also contribute, so the assemblage is most likely pulling from the smaller waterway to the south of the site.

Conversely, the deeper portion of the Spanish Fort site – termed NonEbena, as it did not contain *Fusconaia ebena* – was pulling the largest amount of its shell from a small river or large creek habitat. The current closest is the small waterway south of the site, which may have contributed more during this time period. The river also may have been located in a different area, inhabiting one of the now defunct riverbeds.



Figure 3.7 UNIO-delineated riverine catchment space for the Spanish Fort (22SH500), Little Spanish Fort (22SH522), and Milner Place (22YZ624) sites.

Dual catchments for Spanish Fort in blue (upper level) and indigo (lower level), Little Spanish Fort in purple, Milner Place in green. Linear features are omitted from analysis; they are man-made.

In total, 93.8% of Little Spanish Fort's assemblage came from a large river habitat (Table 3.15). Therefore, the large river that the site is situated on is likely the only regular

source of mussels for this site. The remaining portion, related to a small river or large creek habitat, may be the southern portion of the waterway south of Spanish Fort. It may also be the branch of the Yazoo River between Milner Place and Little Spanish Fort, if this was a small creek before capturing the majority of the river (see Appendix A). The waterway that is now the modern connection between the Yazoo and Sunflower rivers would most likely have been a smaller stream, if it existed at all.

Table 3.14 Habitats from Spanish Fort (22SH500)

Habitat Type	Percentage
<i>Robust shell strata</i>	
Large river, swift current, gravel or gravel-sand substrate	44.0%
Large river, stagnant current, sand-mud or mud substrate	29.2%
Large creek, slow current, mud substrate	26.7%
Waterbody, moderate current, gravel-sand or sand substrate	0.1%
<i>Gracile shell strata</i>	
Small river or large creek, slow to stagnant current, mud substrate	53.2%
Large river or medium river, moderate current, sand-mud substrate	27.3%
Waterway, 30-60 cm deep, stagnant current, mud substrate	19.5%

Table 3.15 Habitats from Little Spanish Fort (22SH522)

Habitat Type	Percentage
Large river, swift current, unknown substrate	93.8%
Small river or large creek, moderate to slow current, unknown substrate	6.2%

Milner Place likewise drew the majority of its shell from the large river habitat. The large oxbow lake to the south of the site shows that the river used to extend farther. It is therefore included in the delineated catchment because it would have been a river channel in the Late Holocene (Saucier 1994). The smaller waterway entering the buffer zone from the north was also once connected to the main river channel. This waterway likely provided the medium and small river species, as it varies in width along its length.

Table 3.16 Habitats from Milner Place (22YZ624)

Habitat Type	Percentage
Large river, swift current, unknown substrate	78.0%
Large river, slow current, mud substrate	8.6%
Medium river, slow to stagnant current, sand-mud substrate	8.0%
Small river or large creek, swift current, gravel or gravel-sand substrate	2.2%
Large river, slow to stagnant current, cobble-gravel or gravel substrate	2.2%
Small river or large creek, moderate to slow current, gravel or gravel-sand substrate	1.1%

The outlining of catchments for all the sites listed provided the ability to present all catchments at once on a map, Figure 3.8. Most are observed to be situated very close to each other. The sites located in the southern portion of the Yazoo River basin are the most illustrative of the population density existing during this period, where the catchments are all constricted and closely packed on the landscape.

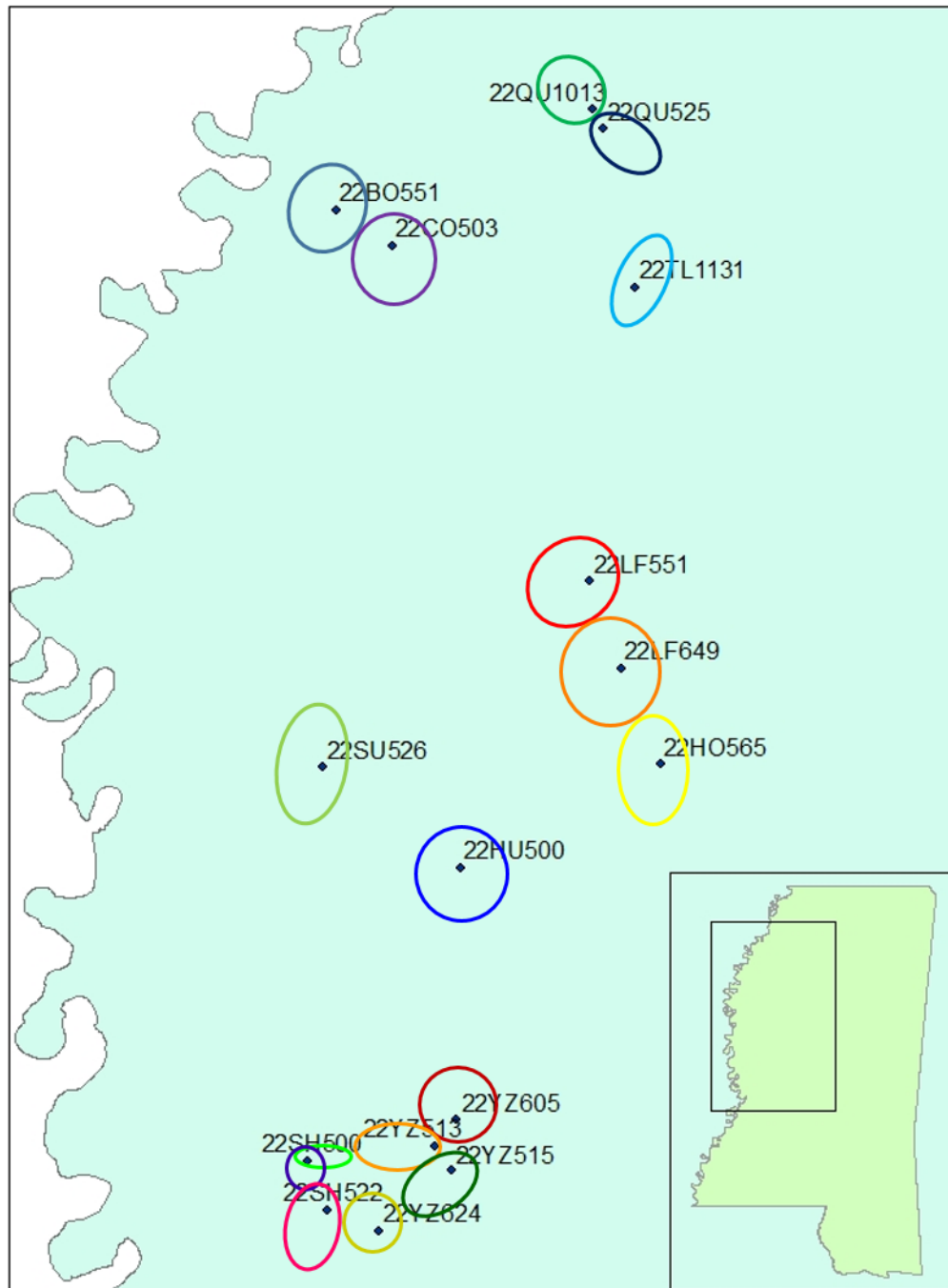


Figure 3.8 UNIO-delineated aquatic catchments for all sites in the Yazoo River basin.

22BO551: blue; 22CO503: purple; 22QU1013: green; 22QU525: navy blue; 22TL1131: light blue; 22LF551: bright red; 22LF649: orange; 22HO565: yellow; 22SU526: light green; 22HU500: bright blue; 22YZ605: dark red; 22YZ513: light orange; 22YZ515: hunter green; 22YZ624: mustard yellow; 22SH522: pink; dual catchments for 22SH500 in bright green (upper level) and dark blue (lower level).

Tombigbee Sites

The northern Tombigbee sites may be impossible to map due to the extreme nature of the human modification of the landscape. The Tibbee Creek, Shell Bluff, and Kellogg sites have all seen major impacts when a dam was constructed on the Tombigbee as part of the construction of the Tenn-Tom waterway, inundating some sites and changing the character of the surrounding river. Catchment delineation is completed to the best of my abilities, but should be understood to be more tentative in this region.

The Tibbee Creek site draws the bulk of its shell from a small river habitat, presumably the Tibbee Creek itself. The site does draw from the nearby large river, but only 34.6% of the assemblage is related to this habitat. Therefore most of the catchment for this site must come from areas and waterways that are now no longer present to the west of the site.

Table 3.17 Habitats from Tibbee Creek (22LO600)

Habitat Type	Percentage
Small river, moderate current, gravel or gravel-sand substrate	65.1%
Large river, swift current, gravel to sand substrate	21.3%
Large river, swift to moderate current, cobble-gravel substrate	13.2%
Large river, slow to stagnant water, cobble-gravel or gravel substrate	0.1%
Waterway, slow to stagnant current, sand-mud or mud substrate	0.1%

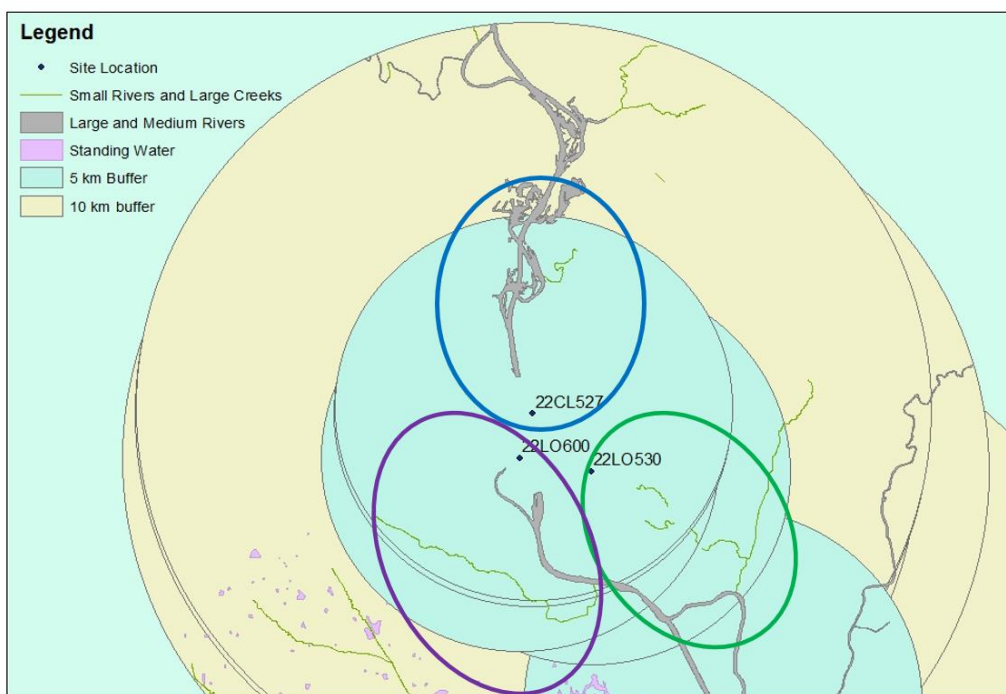


Figure 3.9 UNIO-delineated aquatic catchments space for the Tibbee Creek (22LO600), Shell Bluff (22LO530), and Kellogg sites (22CL527).

Catchment outline for Kellogg in blue, Shell Bluff in purple, Tibbee Creek in green.

Table 3.18 Habitats from Shell Bluff (22LO530)

Habitat Type	Percentage
Small river, moderate current, gravel-sand substrate	76.5%
Large river, swift current, cobble-gravel substrate	12.1%
Medium river, slow to stagnant current, sand-mud or mud substrate	11.4%

Shell Bluff likewise has 76.5% of its shell remains related to a small river habitat, and only 12.1% from the large river. The closest small river is within the site's 5 km buffer, but there is a substantial amount of the large river between Shell Bluff and where the small river joins, probably more than should be expected to produce only 12.1% of the shell. Either this river used to connect closer to the site, or other small rivers in the area have been obliterated by the construction. Nevertheless, the most reasonable region for the catchment of Shell Bluff is southeast of the site, incorporating parts of the large, medium, and small rivers still present.

Table 3.19 Habitats from Kellogg (22CL527)

Habitat Type	Percentage
Large river, swift current, gravel or gravel-sand substrate	86.1%
Small river or large creek, moderate to slow current, gravel or gravel-sand substrate	11.4%
Small river or large creek, slow current, sand-mud substrate	2.4%

The area north of the Kellogg site, where the catchment space is most likely to be, due to the presence of Tibbee Creek and Shell Bluff catchments to the south, is the part most heavily impacted by the construction of the Tenn-Tom waterway. The straighter main Tenn-Tom is visible, as well as the convoluted parts of the river that existed before the construction of the waterway. This makes this area particularly hard to define.

Kellogg drew mainly from the large main river, but also has small river habitats contributing, as well as a small creek or lake. These smaller habitats have likely been destroyed in the modification of the river, but the vestiges of a small river are visible on

the eastern side of the main river channel. Therefore I extended my catchment estimate to include this stream, plus a little beyond to account for other possible habitats that have been destroyed by the construction.

The area near Vaughn Mound has also been subjected to some river diversion, although not as extreme as the area to the north. A straighter channel was inserted to cut off the meander of the river near Vaughn Mound, but the original channel remains. Although the site is located on this large river, a medium river contributes the majority of the shell assemblage. The large river does contribute, but it is the second most productive habitat for this site. The small river habitat is likely the small river southwest of the site, but as it only contributes a little less than 10%, not much of it would have been exploited. Therefore, the hypothesized catchment is mostly limited to the medium river to the east of the site, and the large river the site is located on.

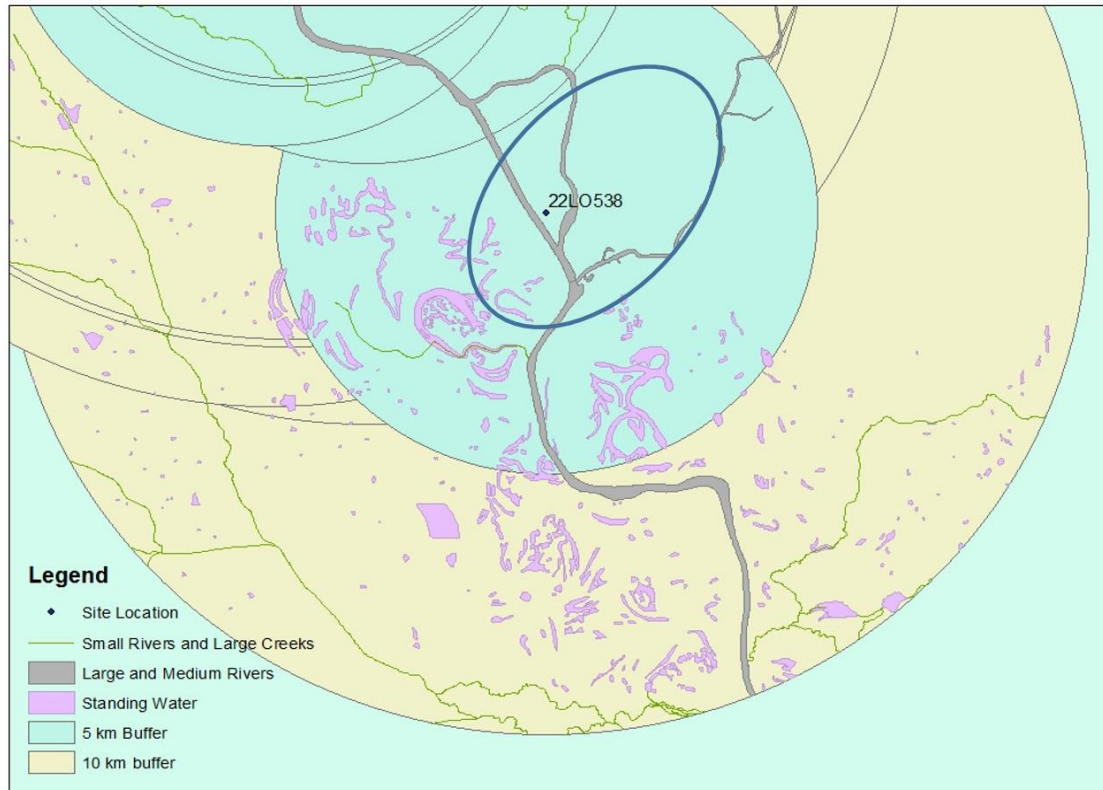


Figure 3.10 UNIO-delineated riverine catchment space for the Vaughn Mound (22LO538) site.

Table 3.20 Habitats from Vaughn Mound (22LO538)

Habitat Type	Percentage
Medium river to large creek, moderate to slow current, gravel-sand substrate	63.3%
Large river, swift current, gravel or gravel-sand substrate	28.8%
Small river, slow current, mud substrate	7.9%

The portion of the Tombigbee River located in Alabama has also seen a shift in its water patterns. The construction of a dam south of the sites resulted in the formation of Gainesville Lake, so what were once flowing river channels are now standing water.

Because of this modern impact, this region will also take some effort to decipher, and may likewise be more conjectural than the sites from the Yazoo River Basin.

Because 59.4% of the shell from the Lubbub site came from small, slow rivers, the preponderance of small rivers north of the site is the most likely major point of exploitation, as they are the closest. They also run through areas marked as standing water, which is further evidence that they are slow-moving streams. The straighter large river in the main channel flows fairly quickly northwest of Lubbub, as evidenced by its straighter flow, and thus provides the percentage of shell that comes from a large swift river. Where the river flows slowly and is interpreted as standing water accounts for the shell related to stagnant, muddy water, while the medium river northeast of the site can provide moderate to slow current and sand-mud substrate.

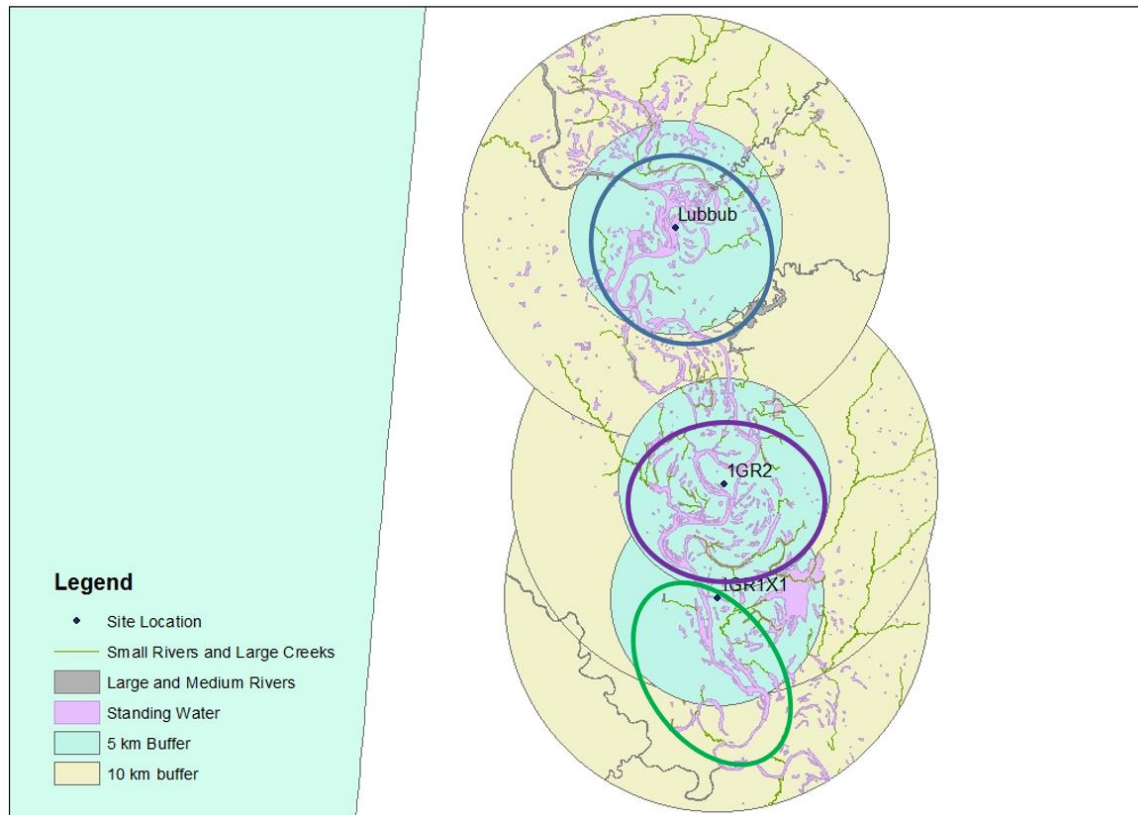


Figure 3.11 UNIO-delineated riverine catchment space for the Lubbub, 1GR1X1, and 1GR2 sites.

Catchment outline for Lubbub in blue, 1GR2 in purple, 1GR1X1 in green.

Table 3.21 Habitats from Lubbub

Habitat Type	Percentage
Small river or large creek, moderate to slow current, gravel or gravel-sand substrate	59.4%
Large river, swift current, gravel or gravel-sand substrate	39.9%
Small river, slow current, mud substrate	0.7%

Table 3.22 Habitats from 1GR2

Habitat Type	Percentage
Large river, swift current, gravel or gravel-sand substrate	65.8%
Small river or large creek, moderate to slow current, gravel-sand substrate	33.6%
Waterway, slow or stagnant current, mud substrate	0.6%

At 1GR2, however, the largest proportion is from a large river with swift current. This is most likely the large river that the site is situated on, but the conditions of the river have changed enough to make individual habitats unrecognizable. As the remaining percentage of the shell is from small rivers with moderate to slow flow, the habitat probably extends to the north of the site, where there are many small rivers that feed into the large river. While extension to the northwest would encounter an uninterrupted stretch of small river, this would assume that the shells are worth transporting over a larger distance when they would be available much closer to the site in the shorter small rivers to the north. It is also likely constricted on the south due to the presence of the 1GR1X1 site.

Table 3.23 Habitats from 1GR1X1

Habitat Type	Percentage
Large river, swift current, gravel or gravel-sand substrate	73.1%
Small river or large creek, slow current, gravel-sand substrate	25.8%
Waterway, slow to stagnant current, mud substrate	1.1%

Like 1GR2, 1GR1X1 has a majority from a large swift river, again the main channel of the river that it is situated on. 1GR1X1 draws slightly less from small rivers than 1GR2, and slightly more from this large river habitat and the surrounding standing water, but the associations are very close. The territory space abuts the territory of 1GR2 north of the site, and then appears to extend to cover the aquatic resources within the remaining 5 km buffer, though probably not expanding much past the main channel of the river. East of the site appears to be a floodplain, where the small river can inundate and possibly make passage impossible.

Although these hypothesized catchments in the Tombigbee River Basin are, as previously stated, much more conjectural than the Yazoo Basin sites, the method was employed nonetheless to evaluate its applicability in significantly disturbed environments. It was still possible to differentiate on the landscape where prehistoric waterways should have been, even though there had been significant impact. This shows the wide applicability of this method.

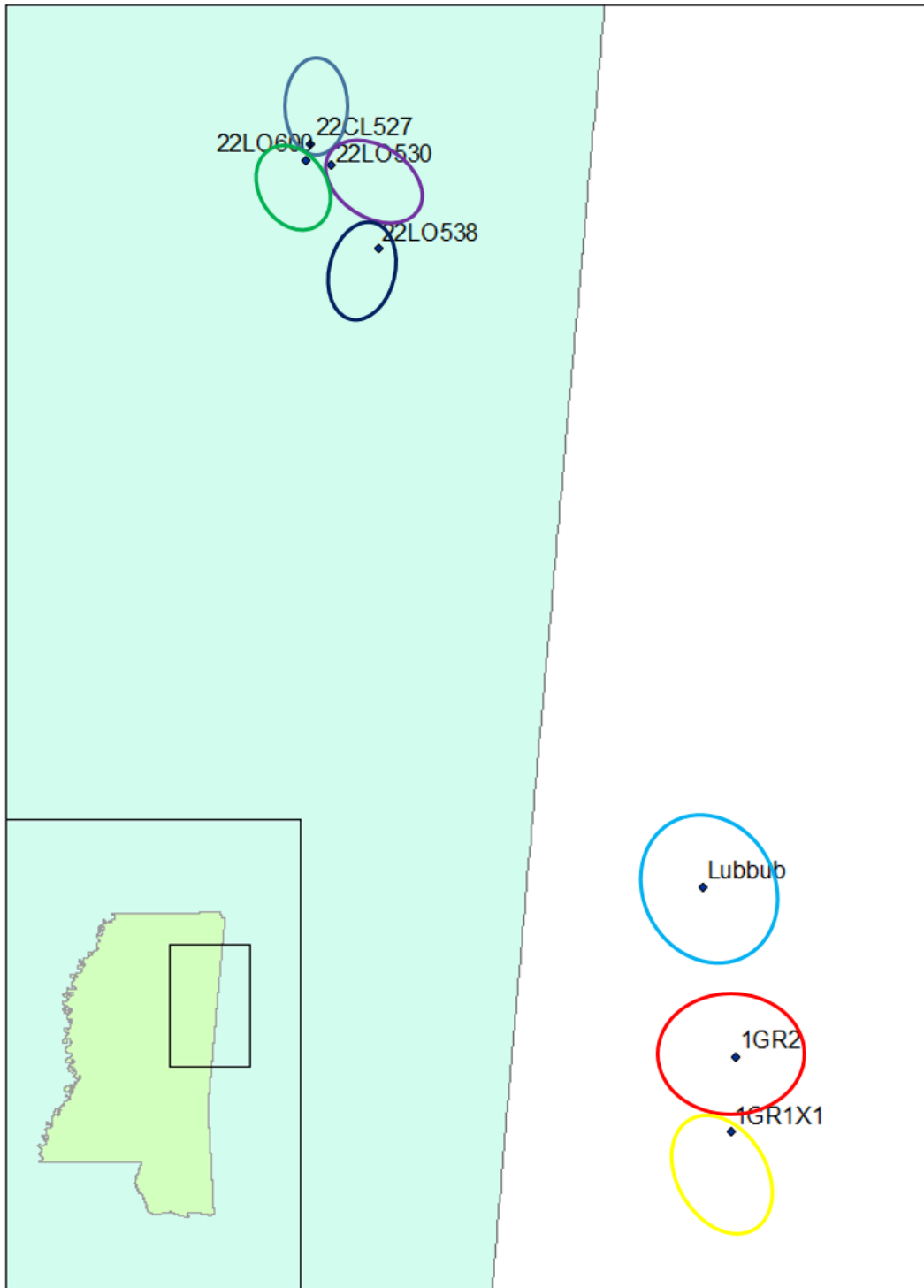


Figure 3.12 UNIO-delineated catchment space for all sites in the Tombigbee River basin.

22CL527: blue; 22LO600: green; 22LO530: purple; 22LO538: navy blue; Lubbub: light blue; 1GR2: red; 1GR1X1: yellow.

Detrended Correspondence Results

As previously noted, the ordinations in the Yazoo Basin were performed by sub-basin, in an attempt to reduce analytical noise. The results of the ordination from the Yazoo River are presented in Figure 3.13. The main bulk of the assemblages are not separated very far along Axis 1, which is the axis that represents most of the variation in the data, with the exception of 22QU1013 and 22YZ515. While 22HU500 is aligned with the rest of the sites along Axis 1, it is far separated vertically along Axis 2, which represents as much of the variation not accounted for by Axis 1 as possible. When the main matrix of the ordination is examined in regards to these sites, these sites are separated based on species contained that are not present in the other sites. 22QU1013 contains 1 *Actinonaias ligamentina* and 1 *Villosa vibex*, 22YZ515 has 2 *Elliptio crassidens*, and 4 *Truncilla donaciformis* were recovered from 22HU500.

When the majority of the sites are examined without these outliers, it seems that for the most part the spatial relationships observed by Peacock (2002) hold constant for the Yazoo River. All sites in Yazoo County are located fairly close together with regard to Axis 1, and the variation along the second axis that is pulling 22YZ624 more positively along this axis could be related to sample size, as this site only has 555 valves total, while 22YZ513 and 22YZ605 have 3,469 and 5,740 total valves respectively. It could also be related to 22YZ624 being located closer to the confluence of the Yazoo and Sunflower Rivers, so other species present in the Sunflower river are affecting the variation.

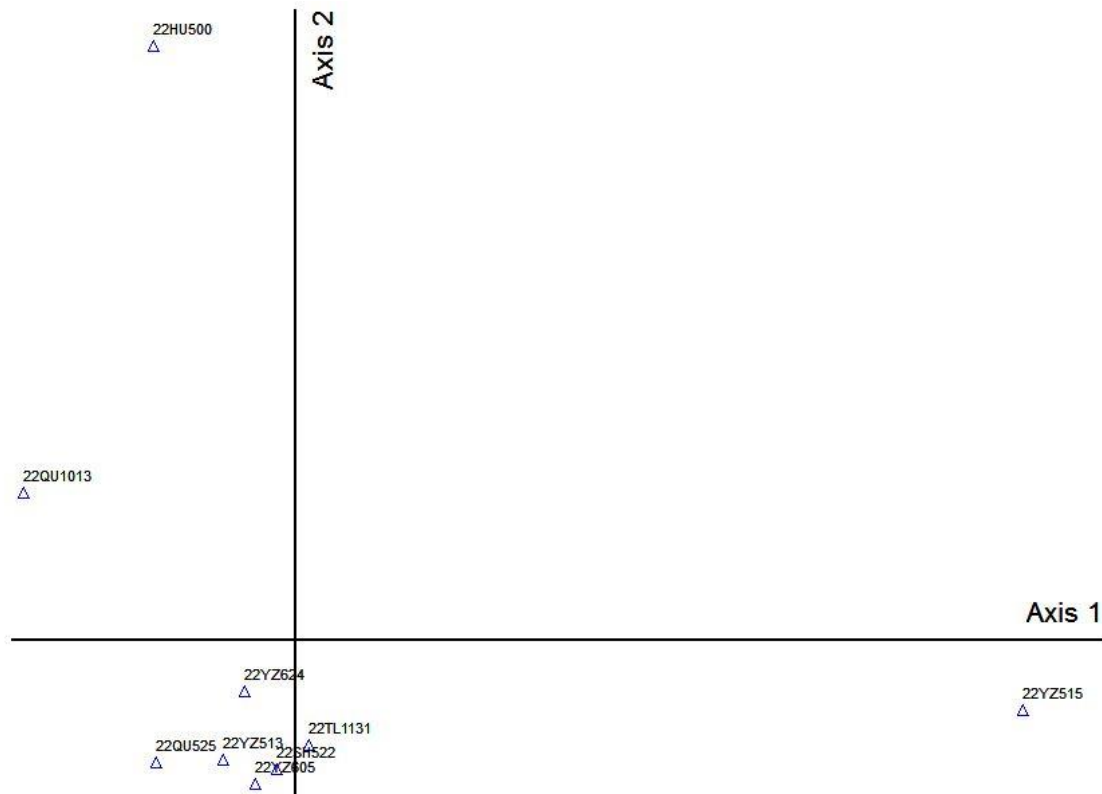


Figure 3.13 Results of Detrended Correspondence Analysis of the sites along the Yazoo River, Mississippi

It is a little more distorted than the results of the Tombigbee, however. Although the most northerly assemblages, the two sites from Quitman County (22QU525 and 22QU1013), are both negative along Axis 1, the sites from Sharkey County and most sites from Yazoo County are more negative along the same axis than the site from Tallahatchie County, which is a reversal of north-south order within the river. However, when corrected for outliers (Figure 3.14), a clearer north-to-south order is observed, with north being oriented negatively along Axis 1, proceeding southward as location along this axis becomes more positive.



Figure 3.14 Yazoo sites without outliers.

The smaller number of sites along the Big Sunflower River made its ordination easier to observe. The Big Sunflower sites are more spread out along Axis 1, with the northernmost sites strongly negative along this axis, but the southern sites strongly positive, with one exception. Site 22BO551 is strongly positive along Axis 1 even though it is the northern-most site in this assemblage. The separate assemblages from the 22SH500 site also separate along this axis, with 22SH500N trending more towards the northern sites. This corroborates well with the combined UNIO and GIS analysis, where the catchment shifted southward after the river changed character.

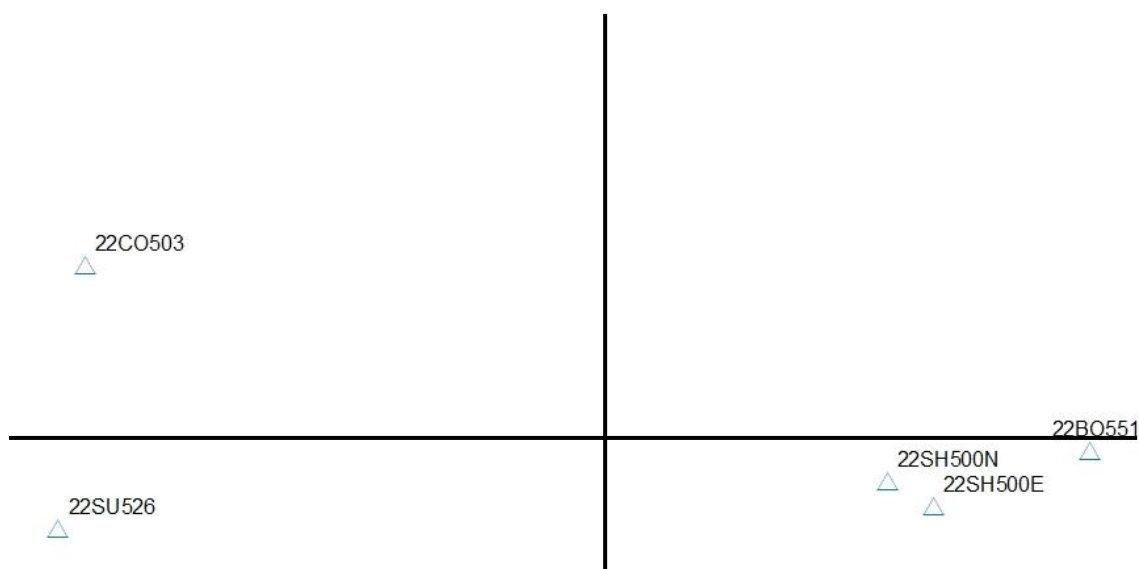


Figure 3.15 Results of Detrended Correspondence Analysis along the Big Sunflower River.

The major variation between the northern sites appears to be in Axis 2. While 22CO503 and 22SU526 are closely situated along Axis 1, in Axis 2 they are spread out, with 22CO503 shifting positive along this axis and 22SU526 trending more negative. 22BO551 appears to be an outlier within its northern group along both axes. In the DCA analysis, this site has more in common with the southern 22SH500 site than its northern counterparts.

CHAPTER IV

DISCUSSION AND CONCLUSION

Detrended Correspondence

While, overall, the correspondence analysis within the Yazoo river basin is not as clearly demarcated spatially as the pattern Peacock (2002) found in the Tombigbee River drainage, the most reasonable explanation for this variability is the characteristics of the rivers themselves. The Tombigbee River is a fairly straight, entrenched drainage, and tributaries drain directly into the main river channel. By contrast, the Yazoo river drainage is composed of several large rivers, each with its own sub-basin, which resulted in the need to use multiple detrended correspondence analyses to describe the variation. Each sub-basin, both the Yazoo River and the Big Sunflower River, is extremely dendritic, and also has a large number of meander belts and cut-offs. This makes the variation in these rivers more complex and difficult to describe, as horizontal variation in the stream is also a factor.

Though the trend observed by Peacock (2002), that the sites appear in mathematical space in the same way they occur in physical space, was generally supported in the Big Sunflower and Yazoo River drainages, there was one main point of deviation from the overall pattern. Site 22BO551 was excluded from its geographical counterparts along both of the first two axes of variation. Although the results from the UNIO analysis showed that this site was just as constrained spatially as others, the faunal

composition seemed to have more in common with the sites located much farther south in the drainage, though it was separated from these assemblages by over 150 km.

First, it is completely possible that the location of 22BO551 in the DCA is related to sample size bias and so the assemblage should be excluded. However, the placement of this site may also be related to other environmental factors. It is located closest to the two assemblages from 22SH500, which are located about 40 km from the confluence of the Yazoo and the Mississippi rivers. If 22BO551 is removed from the analysis, then the sites are ordered in space along the Big Sunflower from its headwaters to the Mississippi River. The location of 22BO551 in the DCA makes it look as though it is closer to the Mississippi River than the rest of the sites along the Big Sunflower River.

This, objectively, is a true statement. The Mississippi River is located in a straight-line distance about 13 km away from 22BO551, even though it is in the northernmost region of the Big Sunflower River. In antiquity, the site may have been located even closer to the Mississippi; as Saucier's (1994) maps show, the site is located near several ancient cutoffs of the ancient Mississippi River, and one of these may have been flowing when the site was occupied (Figure 4.1). Therefore, the inhabitants of the site may have been exploiting streams that drain not only to the Big Sunflower, but also more directly to the Mississippi River. The addition of mussels from tertiary streams outside the Big Sunflower drainage make it appear as though the site is in a different location when plotted in mathematical space. Therefore, it is not necessarily the latitudinal location of the site that influences its placement in the DCA, but rather the proximity to the Mississippi River, that influences the mathematical position.

When the DCA results are analyzed for individual species, several likely candidates can be identified as contributing the most to the relative positions of the sites in the ordination. The 22SH500 assemblages share a high count of *Ligumia subrostrata* with 22BO551, which is not seen in the other two assemblages. Likewise, these share a lack of several other species: *Obovaria subrotunda*, *Strophitus undulatus*, and *Villosa lienosa* all appear to be important in influencing the location of sites along the horizontal axis. BO551 also contains a relatively large amount of *Uniomerus declivis*, which is not shared by any other sites, which places it further from the 22SH500 assemblages.

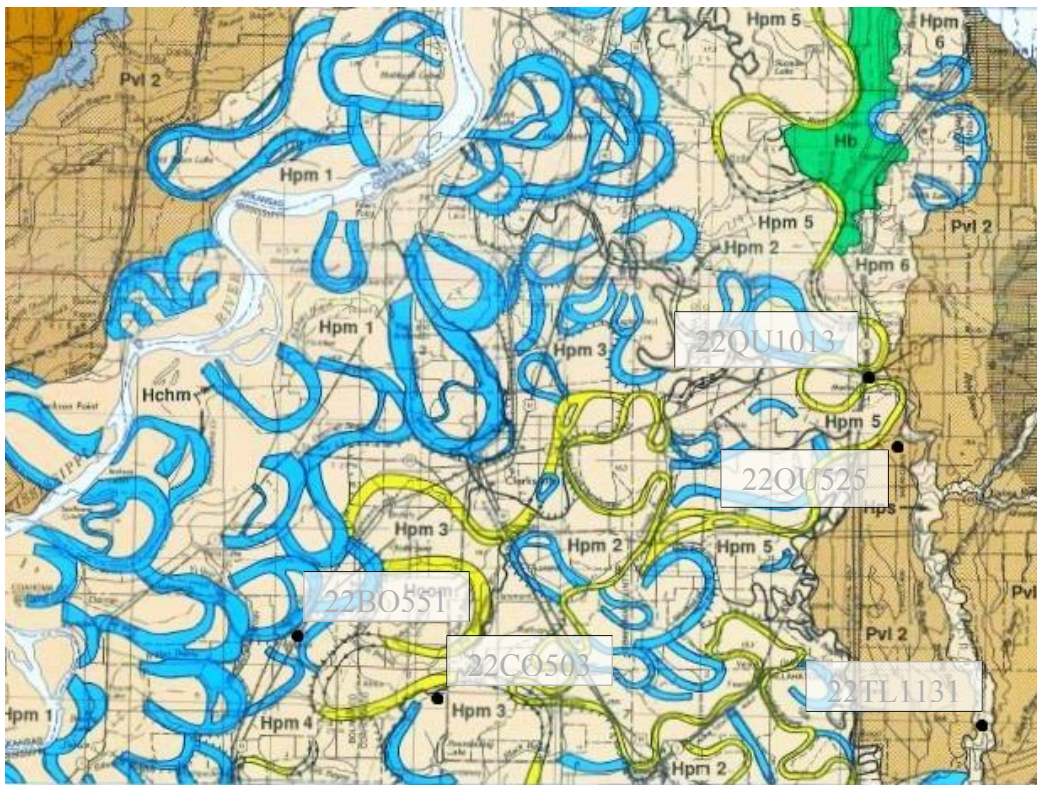


Figure 4.1 Upper Sunflower and Upper Yazoo sites plotted on Plate 7 of Saucier (1994).

An Evaluation of the UNIO Program

The UNIO program was certainly an integral part of this research, and I could not have completed this project without it. Nevertheless, its utility for studying archaeological contexts should be evaluated. For comparative purposes, the graphs produced by the UNIO program are provided for the Kinlock site (22SU526), as well as the graphs produced by the modified sensitive UNIO that I developed for this project. I use the Kinlock site as it is a robust assemblage that has been sampled to redundancy, so all species present should be represented (Mitchell et al. 2016).

The removal of non-sensitive species had the most effect on the graphs for waterbody type and substrate composition. With conventional use of the UNIO program, the graphs, while providing an excellent visual aid, make it difficult to discern when there are multiple waterways contributing to the assemblage. It was the spreadsheet within the program that made it possible to pick out individual waterways, as the weighted table identified where two species would not have been able to live in the same habitat.

The UNIO program is a very powerful tool to help reconstruct paleoenvironmental conditions. However, it should not be applied wholesale, using the assumption that the graphs produced will replicate a single environment from which the material originated. Rather, the species present should be evaluated through the program to determine the specific habitats represented.

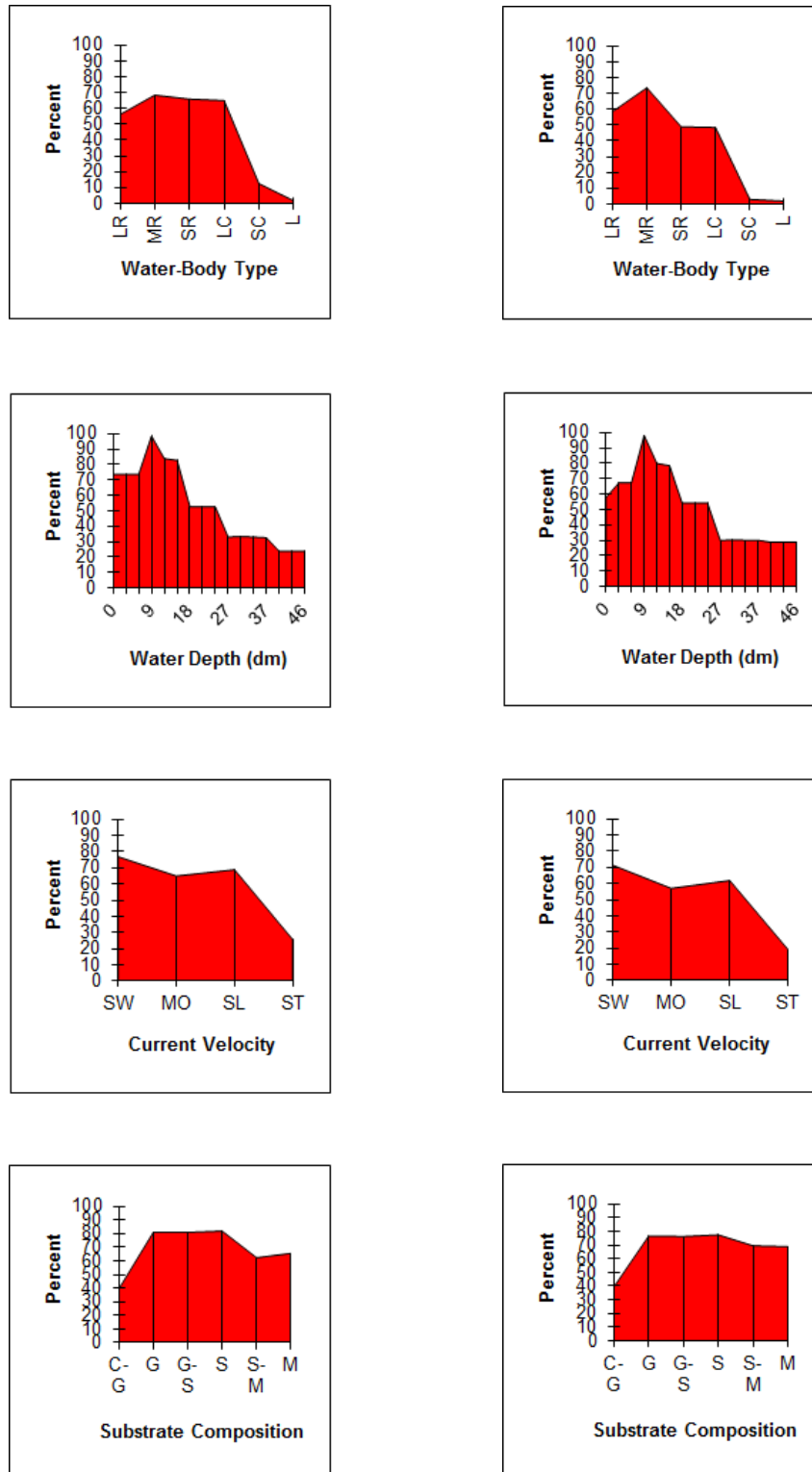


Figure 4.2 Kinlock site graphs for UNIO (left) and Sensitive UNIO (right).

Other problems may also exist when using UNIO for environmental reconstruction. One limitation is the current knowledge of mussel ecology. Often the information contained in mussel guides is broad and vague, and there is no guarantee that the same descriptions mean the same thing when used by separate individuals (Warren 1991). Our limited knowledge of rare, endangered, or extinct species is also problematic for defining the exact habitats of these mussel fauna.

Another complicating factor may be the water depth variable. As previously described, this variable was not included in the sensitive UNIO because few were specific for this characteristic, owing to the number of category divisions within it. If this characteristic is more important to the location of mussels in waterways than other characteristics, then not including it may have introduced a bias in the method against a potentially significant characteristic.

Conclusions

The most illustrative evidence for habitat restriction in this drainage came from the UNIO program. Through the modified version of UNIO, I was able to create hypothetical catchment areas that could be mapped onto the landscape through combining the environmental data from the UNIO program with GIS layers to show how these existed in real space.

Archaeological freshwater mussel assemblages were analyzed from a number of sites to provide multiple tests of this method for habitat reconstruction. The information presented here is significant because it shows not only that this level of precision in mapping prehistoric environments is possible, but it also seems to confirm the hypotheses of range constriction in the Southeast during the Late Woodland period. This type of

mapping should also be able to pinpoint areas where other sites should be, if the ranges constructed do not cover certain areas.

A goal of this thesis was to evaluate the ordinal power of DCA when applied to dendritic stream systems. Though the DCA for the Yazoo basin rivers did present a more-or-less spatially accurate ordination, the ordination was not nearly as clearly defined in Peacock's (2002) analysis of the Tombigbee river drainage.

So, while landscape conditions may influence the strength of an ordination, the coupling of UNIO and GIS was still able to show that exploitation of freshwater mussel fauna was mostly local. This study has provided a new way to use the UNIO program to evaluate the prehistoric aquatic environment. This method has proved equal to the task of presenting hypothetical catchment sizes and shapes for multiple river drainages, and enabled the expansion of the UNIO program to include species that had not been quantified for this method, which will increase the program's utility in further research. Also, the program's equal usefulness with either MNI or NISP data was demonstrated. As at Spanish Fort, it also showed that, if shell is present in multiple contexts at a given site, UNIO can be used to track changes in the riverine environment through time. This application is useful for when the current conditions do not match the conditions produced when examining archaeological indicators for environment.

This method also served to test ethnographically derived models of catchment space. The average foraging radius, measured along the long axis of the derived catchments, was about 6.92 km. This measurement is slightly larger than Kelly's (1995) predicted 6 km threshold for the maximum foraging range that could be expected before migration or intensification occurred. This is also significantly smaller than Binford's

(2001) 20 km estimation of maximum foraging radius; although Binford qualifies this statement as being applicable only to very specific societies and further calculates his estimated average at 8.28 km, this still exceeds the radii shown by the mussel assemblages in either the Yazoo or the Tombigbee River drainages (see Figure 4.3)

It should also be noted that the average foraging radius differs by drainage. Sites along the Tombigbee averaged a foraging radius of 5.07 km. The Yazoo River and Big Sunflower River sites averaged higher, at 7.93 and 7.85 km respectively. The Big Sunflower River, however, is only represented by 3 sites, so this may not be completely accurate. Further investigation into this river system should be conducted to determine whether this pattern is consistent.

Sites also could not be counted upon to exhibit similar catchment radii as their neighbors. Many of the sites in the Lower Yazoo group, located in Sharkey and Yazoo counties, had similar sizes, with five of the six sites ranging from 6.4 km to 7.39 km. However, the remaining site in this group, 22SH500, had an effective radius of only 4.92 km. The sites 22HO565, 22LF649, and 22LF551, all located close together along the Yazoo River, had similar radii: 8.63, 9.56, and 8.43 km, respectively, but this pattern did not extend to the northern portion of the Yazoo. The two sites in Quitman County, though located about 7 km away from each other along the Little Tallahatchie River, had more than a two and a half km difference in their foraging radii. Conversely, sites in the northern Big Sunflower River basin, about 38 km away, had barely a 75 m difference in radii. These differences may be related to group size, power differentials, or other unidentified neighbors. It should also be noted that these catchments are restricted to the riverine environments, and should not be taken to represent terrestrial catchment as well.

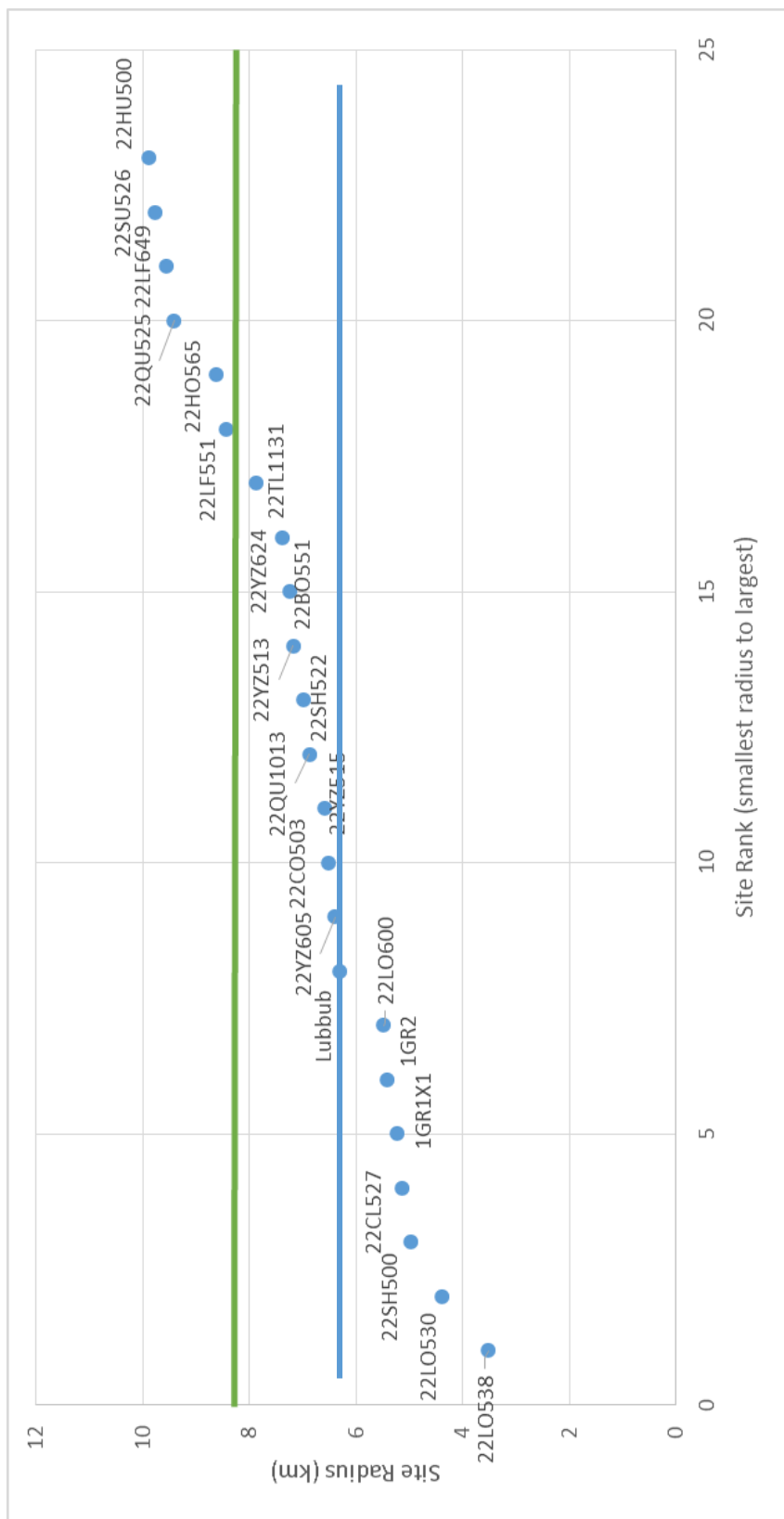


Figure 4.3 Scatterplot of catchment radii for all sites examined. Kelly's (1995) 6 km threshold in blue, Binford's (2001) 8.28 km threshold in green.

When all catchment radii for the sites examined are placed on a single graph, there appear to be several points at which the radii begin to asymptote. The first is approaching Kelly's (1995) threshold for migration or intensification, shown in blue in Figure 4.3. As sites approach this threshold, there appears to be some constraint to the ability to expand the catchment farther, unless it can be extended a fair amount; the difference between the catchment radii of the site closest to the 6 km threshold and first above is almost a full kilometer. It is also of interest to note that all of the Tombigbee sites fall below this 6 km threshold, except for Lubbub, which is the first above this threshold.

Catchment radii then appear to gradually increase before appearing to asymptote again close to 9 km. This is just outside Binford's (2001) 8.28 km foraging limit, marked in green in Figure 4.3. Another separation of just under a kilometer marks the difference to the next range of sites, which all exhibit fairly large catchment radii. In order from smallest to largest, these are the Shady Grove, Palusha Creek, Kinlock, and Belzoni sites. These vary in relation to each other by less than half a kilometer. Of these four sites, it should be noted that at least two, Kinlock and Belzoni, are time-averaged assemblages that may represent multiple occupations, where earlier catchments may have been larger.

Recommendations for Future Research

Taken as a whole, Figure 4.3 seems to validate Kelly's (1995) assertion that something is constraining hunter-gatherer foraging distance at around 6 km. While further investigation of this is beyond the scope of this thesis, the lack of site catchments between 5.48 km and 6.32 and between 8.63 and 9.42 km merit further study to determine whether this is a true pattern or an artifact of not having tested enough sites.

One complicating facet of the analysis was the possibility that microhabitats within a larger habitat contributed to the mussel assemblages. To better understand this phenomenon, this method can be developed further by testing it on modern mussel assemblages, where the characteristics of the river are known. With the river variables controlled for, the variability shown through analysis of the mussels should be indicative of the observed river characteristics. Deviations from this expectation would be indicative of microhabitat contributions. Assuming these are, in fact, observable by UNIO, this could represent a new and powerful addition to paleoenvironmental studies.

Another way to test the results from the UNIO analysis directly on archaeological assemblages is to use shell sizing. Some freshwater mussel species exhibit great phenotypic plasticity depending on the size of waterways they are located in (Peacock et al. 2010). Some, such as *Lampsilis straminea*, exhibit this plasticity to so great a degree that the upstream and downstream phenotypes have been categorized as separate subspecies; *L. s. straminea* is the upstream phenotype for smaller, swifter rivers, while *L. s. claibornensis* is the downstream phenotype representative of larger, slower rivers (Peacock et al. 2010). Other species can also be used to test stream size by mussel size (Peacock and Seltzer 2012). This sizing can be used independently of the UNIO analysis to test whether the UNIO results are similar to those from other types of analysis.

Further analyses could include using the isotopic signatures derived from the shells as an independent line of evidence for catchment space. Rivers acquire different isotopic signatures from the underlying geology of their beds. Therefore, because mollusks build their shells from the water they inhabit, each mussel shoal should have a

distinct isotopic signature. Sites located close to each other on the landscape should then also have distinct isotopic signatures, if constraint is happening.

While over 60 shell rings have been found in the Mississippi Delta (Carlock 2015), very few have been studied actively (Peacock et al. 2011). Examination of the function, location, and chronology of these sites has only just begun (Carlock 2015; Raymond 2014). Through integrating the previous work in the region and showing how the sites in the Mississippi Delta relate to their neighbors, this thesis contributes to literature on prehistoric catchments, as well as addressing some questions of methodology that can be applied further to understand site catchment and paleogeomorphology.

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APPENDIX A

EXCAVATIONS AT THE SPANISH FORT SITE (22SH500)

To augment the data from Peacock (2011), a small field project was conducted at the Spanish Fort site (22SH500) in Sharkey County, Mississippi. The site is located near the town of Holly Bluff, on the banks of the Sunflower River. It is composed of a large Middle Woodland period earthen ring, with a smaller Late Woodland period shell ring midden located in the southeastern corner of the larger ring. The site was first recorded by C. B. Moore in the early 1900s, and some excavation was done by Philip Phillips in 1949 (Phillips 1970). In the half-century between, about two-thirds of the northern portion of the site was repurposed for farmland. Luckily, the dense shell midden is mostly in the southern portion of the site, and remains fairly undisturbed, with the exception of Phillips' unit. In modern times a house and barn have been built within the enclosure of the shell ring, but they disturb the archaeological deposits very little. In 2014, a single 50 x 50 cm shovel test pit (STP) was dug near the foundations of the house by avocational archaeologists, including the landowner, Clay Adcock, and friends Eddie Templeton and Benny Roberts.

We were provided with field notes from the 2014 excavation by Benny Roberts. According to the notes taken by Mr. Roberts, the excavators had set up a grid for the site that was approximately 30° east of magnetic north, aligned with a concrete slab on the property. The three of us re-located the datum used by the 2014 excavators and TU 2014-1. Using a transit for measurement, we determined that the offset employed by the 2014 excavators was closer to 15° east of magnetic north. From these points we were able to place our shovel test pits approximately on the established grid, using the 500N, 500E datum established by Mr. Adcock to keep the work uniform.



Figure A.1 Phillips' plan map georeferenced to aerial imagery.

Plan map from Phillips 1970. 2' LiDAR imagery from the Mississippi Coordinating Council for Remote Sensing and Geographic Information Systems (MCCRSGIS).

When fieldwork began in August 2015, overseen by Jeffrey S. Alvey, director of MSU's cultural resource management office, four shovel test pits were placed in the midden on the western portion of the site in a square on an exposed ridge of midden. These pits were designated STP 2015-1 (east), STP 2015-2 (west), STP 2015-3 (north) and STP 2015-4 (south). STP 2015-5 was placed near where the avocational archaeologists had dug in 2014, closer to the center of the shell ring.



Figure A.2 Spanish Fort site with STP locations.

Inset enlarged to show study area.
2' aerial imagery from MCCRSGIS.

Initial GPS points were taken from the center of each STP with a Trimble GeoXH. Points were later projected into the Mississippi State Transverse Mercator (MSTM) projection, using the North American Datum of 1983 (NAD 1983). Raster imagery was acquired of the region from the Mississippi Automated Resource Information System (MARIS), to create the maps shown here. These data were already in the MSTM projection using NAD 1983.

The shovel test pits were excavated in natural zones with arbitrary 10 cm level divisions. The topmost level, related to historical disturbance, was removed as a single level regardless of depth. Material was then water-screened through nested 1/4-inch and

1/16-inch mesh. Water was acquired by pumping from the Sunflower River. The material collected in each screen was then laid out on shade cloths in the sun to dry. Once dry, the material was bagged by provenience, separated by 1/4" and 1/16" screen size. The water-screening process caused some problems when dealing with exceedingly silty soils, which trapped water and overflowed the 1/16" screen. In one case, shovel test 2015-1 zone B, this resulted in some of the siltiest soils being removed from the 1/16" screen by hand, possibly with some loss of material.



Figure A.3 Molly Keane Ross and Sarah Skibinski excavating shovel test 2015-1.

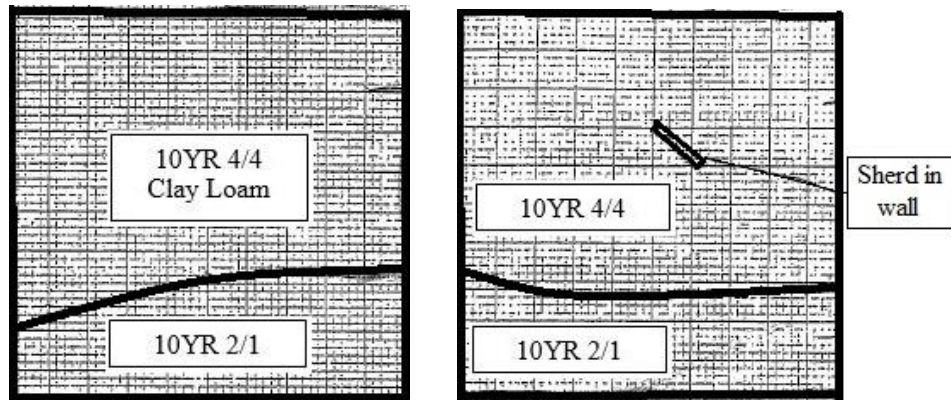


Figure A.4 Soil profile for STP 2015-1, south wall (left) and west wall (right)



Figure A.5 Taking a break while excavating shovel test 2015-2.

From left: Jeffery S. Alvey, Sarah Skibinski, William Harris, and James Strawn.

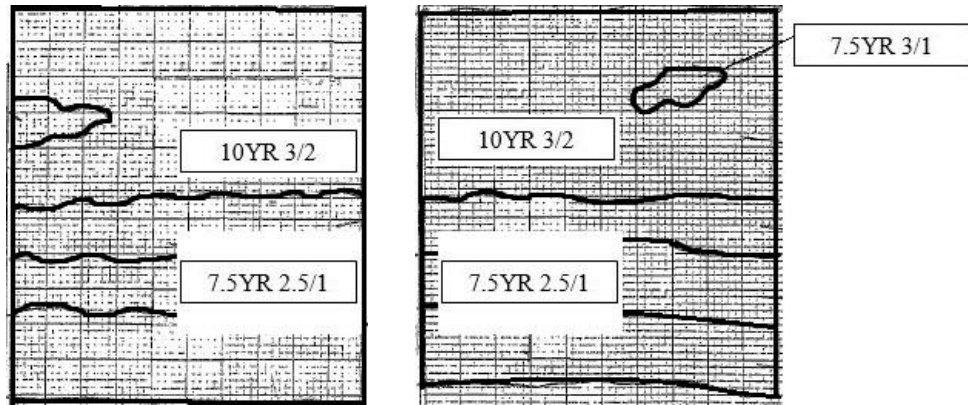


Figure A.6 Soil profile for STP 2015-2, north wall (left) and west wall (right).



Figure A.7 William Harris water-screening material.



Figure A.8 Material from fine screen and large screen laid out on drying cloths.

Once shovel test pits were complete, two profiles were drawn. The north profile was photographed, unless disturbed, in which case the west profile was photographed. Soil samples were taken from the midden layer and from the artifact-bearing stratum below the midden layer, if present. These soil samples were given individual bag numbers separate from the zone they were acquired from.

Large chunks of charcoal, when found below the topmost historical disturbance, were collected for radiocarbon analysis. When uncovered, these were collected with trowels or gloved hands so as to not let the oils from our fingers contaminate the sample, and then wrapped in foil. These were also given individual bag numbers.

While digging STP 2015-1 a disturbance was discovered in zone B-1, which appeared to intrude completely through the midden layer. This zone was very hard to

distinguish from the plow zone of A-1 as it was still mottled; however, it was slightly darker in color. The same disturbance was identified at STP 015-4, where at 30 cmbs it bisected the unit, covering about two-thirds of the STP.

Mr. Adcock was on site, and informed us that there had been a cotton gin on the western portion of the site, which we were previously unaware of. He suspected that we had hit some of the pilings or foundation disturbance. However, he assured us that there must be some relatively undisturbed deposits, having found several potsherds which refit the previous summer. He identified the spot where he had found these sherds, and I decided to place a sixth shovel test pit, STP 2015-6, where indicated, and placed a marker flag so it could be inserted into the grid.



Figure A.9 Intact historic remains at the Spanish Fort site.



Figure A.10 West profile of STP 2015-1.

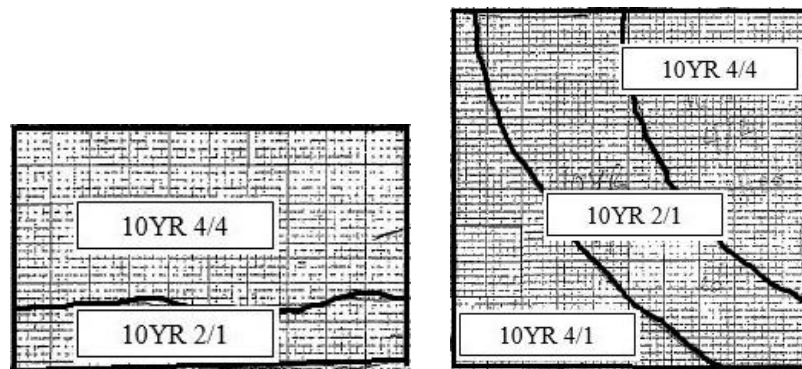


Figure A.11 Soil profile of STP 2015-4, north wall (left) and plan view at bottom of excavation (right).

This pit was tied into the existing grid by taking a compass and traveling at 15° east of magnetic north from the marker flag until reaching a line laid out at 510N. The distance from the 510N line was measured as 9.75 m, and the path intercepted the line 6.75 m east of the stake marking STP 2015-1 at 510N 440E. This gave the southwest

coordinate for STP 2015-6 as 500.25N 446.75E. The southeast corner was obtained by taking a 50 cm measuring tape and placing a flag where this tape intersected a 9.25 measure dropped from the location of 510N 7.25E, 50 cm east of where the compass path intercepted the 510N line. The other two points of the shovel test pit were triangulated normally.

Material that did not get screened in the field due to time constraints was screened later at MSU. To reduce the risk of information loss, the screens used were the same screens we had taken to the site. Screening was done much the same as it had been in the field, except that, instead of being transferred to shade cloths, the 1/4" screen was transferred directly to the 1/8" screens of the drying rack at the curation facility. The 1/16" material remained on shade cloths that were placed on the curation screens, as the 1/8" screen size would have allowed materials captured by 1/16" screen to fall through. These were left on the drying rack at the curation facility, and monitored over the course of the next two weeks for dryness.

Once returned to the Cobb Institute at MSU, the material from the 1/4" screens was given a more thorough washing, and was then sorted into general categories: mussel valves with most of umbo present, ceramic, bone, snail, charcoal, lithic, unmodified stone, and unidentifiable shell. The more complete valves were then subdivided by species and tallied for each provenience. Non-shell artifacts were also tallied, with the exception of charcoal, bone, and unidentifiable shell. Bone was separated into broad categories where possible, such as otoliths, teeth, and garfish scales. One human tooth was recovered from STP 2015-5, Zone B-1, 18-28 cmbs. As no other remains could be identified as human, the possibility of disturbing a burial seems slight, and this incidental

recovery may be more likely to relate to modern disturbance at the site prior to our excavations.

In the process of analysis of the Spanish Fort material, especially the STPs on the western side of the site, it became obvious that there was a spatial discrepancy that could cause the material to be treated as two separate habitat entities. Throughout the topmost layer of soil, which has been disturbed historically, the malacological remains contained more robust species, with denser, thicker shells (e.g. *Quadrula* species, *Fusconaia ebena*). The lower levels lacked these robust species and tended to have higher counts of the gracile species with thinner, more delicate shells (e.g. *Lampsilis* species). This pattern existed on the eastern side, but was much less pronounced, with the 2014 STP producing the robust species down to 60 cmbs.



Figure A.12 Sarah Skibinski water-screening at MSU's Curation Facility.

Initially, this discrepancy was attributed to preservation bias. Historic disturbance of the upper layer of soil would have caused preferential preservation of the robust species in upper levels. When the counts of species were plotted in a species area curve, the top level asymptotes within the first four samples, then remains constant before the addition of a single species in the final sample. The lower-level samples, however, do not begin to asymptote until the sixth sample, continuing to add species.

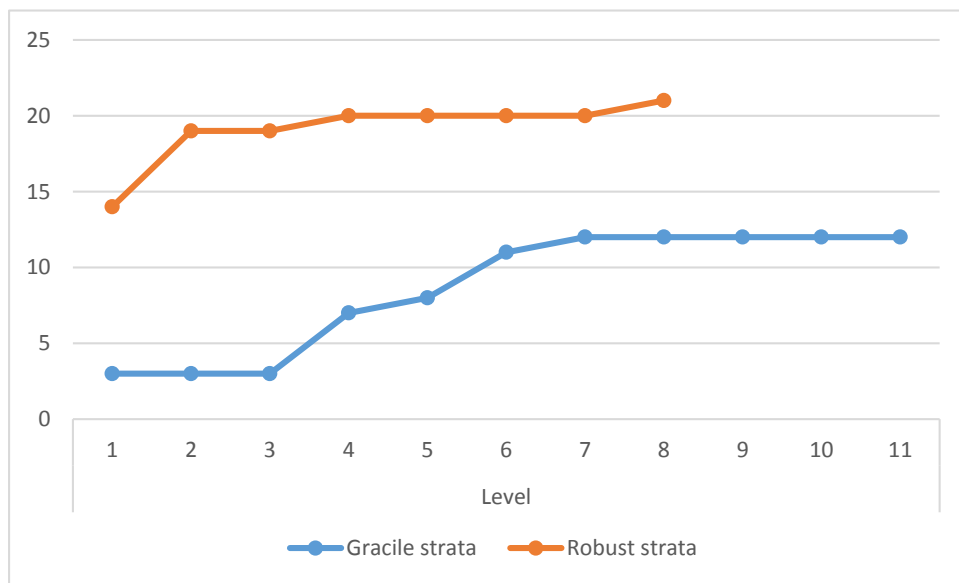


Figure A.13 Species area curves for the upper and lower portions of the Spanish Fort site.

Therefore, although there was some preservation bias in the upper levels, it did not seem to be too drastic. One important aspect of the Spanish Fort investigation was the recovery of the first archaeologically recorded *Pyganodon grandis* mussel, commonly known as the Giant Floater, from Mississippi. The species was represented by a single right valve from STP 3, Zone A, Level 1, a depth of 0 – 39 cmbs. Another extremely

fragile species, and also another first for Mississippi, was also recovered at this site:

Anodonta suborbiculata, the Flat Floater. Eighteen valves of this species were recovered, with seven coming from a Zone A provenience.



Figure A.14 *Pyganodon grandis* valve recovered from the Spanish Fort site.



Figure A.15 One of 18 *Anodonta suborbiculata* valves recovered from the Spanish Fort site.

Other evidence that points to good preservation in historically modified strata at Spanish Fort is that pottery recovered can often be refit to neighboring sherds (Clay Adcock, personal communication). This contributes to the idea that even in locations where there has been extensive development, the historic zone can still contain important data and should not be disregarded or treated as a less important archaeological deposit. It is improper to discard these deposits unless these zones can be shown to be less representative of the site structure (see Peacock and Chapman 2001).

Although a development-related preservation bias could be responsible for the decrease in thin-shelled species recovered in the top layer of soil, it does not explain the lack of the robust species in the lower levels. Therefore it is more likely that the robust species were simply not there when the shells in lower levels were being collected. It is also possible that the excavations at the site were not extensive enough to accurately

describe the overall character of the site; because this pattern seems more pronounced on the western portion, this pattern may be a sampling bias due to the small portion of the site that was surveyed.

The proveniences of the 2015 Spanish Fort excavation are tabulated below, with proveniences listed in STP-zone-level format (i.e. 1A1 is STP 1, Zone A, Level 1). Proveniences containing the robust species are highlighted in green. Recovery of the robust species varies by depth, from 18-39 cm, showing deposition of this stratum to be inconstant across the site. It also appears to grade into the lower stratum, as several zones (2B1, 3B1) show counts of robust species gradually decreasing with depth, rather than an abrupt cessation.

Table A.1 Proveniences of the 2015 Spanish Fort excavation, with robust-bearing zones highlighted in green.

	1A1	1B1	2A1	2B1	2C1	2D1	3A1	3B1	3B2	3B3	3B4	4A	5A	5B1	5B2	6A	6B1	6C1	6D1
Depth	0-39	39-49	0-30	30-38	38-49	49-57	0-19	19-29	29-39	39-49	49-60	0-30	0-18	18-28	28-38	0-24	24-34	34-44	44-54
<i>Amblema plicata</i>	2		2	1				1					1			2			
<i>Anodonta suborbiculata</i>	4			1				3			4					2	2	1	1
<i>Cyprogenia aberti</i>																			
<i>Elliptio dilatata</i>																			
<i>Fusconaia ebena</i>	10		12	1			6	1				3	3			7			
<i>Fusconaia flava</i>			1	1									1						
<i>Lampsilis hydiana</i>	8		3	14					2	1	7			3	3	12	2	30	5
<i>Lampsilis ovata</i>	8		5					2	1		1	1	4	1				3	
<i>Lampsilis siliquidea</i>	1		5				2		1	1	1						2		1
<i>Lampsilis teres</i>	5		12	11			3	1			8					21	3	16	1
<i>Ligumia subrostrata</i>	4		7	2				7	3		3	1	1	1		4	1	8	1
<i>Obliquaria reflexa</i>	2																		
<i>Plectomerus dombeyanus</i>	5		7	1	1		4	1				8	1	1		1			1
<i>Pleurobema rubrum</i>			1									2				3			
<i>Pyganodon grandis</i>							1												
<i>Quadrula apiculata</i>																1			
<i>Quadrula nodulata</i>	1																		
<i>Quadrula pustulosa</i>	1											1							
<i>Quadrula quadrata</i>	1			1								1							
<i>Toxolasma parvum</i>	31	3	38	46	3	26	7	3	7	16	25	10	29	3	14	15	10	5	1
<i>Toxolasma texasiensis</i>			31	37	1	23	2		2	12	4	9	22	1	4	6	8	1	

To further test the differences between the two strata that appear to be observed at Spanish Fort, I applied a Mantel test, the same statistical test used to determine whether the MNI and NISP values were correlated. When the matrices derived from each stratum are compared, the derived p-value of 0.186 is insignificant at the 0.05 significance level. This means that the two matrices are not statistically correlated; the contents of one stratum do not predict the contents of the other. Therefore, I decided to treat the two strata as separate entities for the analysis described in this thesis.

This variation in deposition could be related to an environmental shift in the river characteristics. If an environmental effect, such as the migration of river channels, caused a change in the river environment, this would suddenly have favored different types of mussels. These effects would probably be observed on a gradient in the mussel fauna, as the original mussels would slowly die out as they were being replaced by other species more tolerant to the new environmental conditions.

As previously observed, this could also be related to the relatively small area of the site that was surveyed. It is possible that the locations of the STPs in the site simply encountered an area where a basket of shells from a mussel bed bearing the robust mussels was dumped on top of a load that was from a separate bed that did not have these species. Further investigation into the eastern side of the site, along with a more broad investigation on the western side of the site, should be able to confirm whether these patterns are an artifact of sampling bias.

Table A.2 Proveniences and mussel counts from the 2015 Spanish Fort excavation, zones containing robust species highlighted in green.

	1A1	1B1	2A1	2B1	2C1	2D1	3A1	3B1	3B2	3B3	3B4	4A	5A	5B1	5B2	6A	6B1	6C1	6D1
Depth	0-39	39-49	0-30	30-38	38-49	49-57	0-19	19-29	29-39	39-49	49-60	0-30	0-18	18-28	28-38	0-24	24-34	34-44	44-54
<i>Amblema plicata</i>	2		2	1				1					1			2			
<i>Anodonta suborbiculata</i>	4			1				3			4					2	2	1	1
<i>Cyprogenia aberti</i>																			
<i>Elliptio dilatata</i>																			
<i>Fusconaia ebena</i>	10		12	1			6	1				3	3			7			
<i>Fusconaia flava</i>			1	1									1						
<i>Lampsilis hydiana</i>	8		3	14					2	1	7			3	3	12	2	30	5
<i>Lampsilis ovata</i>	8		5					2	1		1	1	4	1				3	
<i>Lampsilis siliquoides</i>	1		5				2		1	1	1						2		1
<i>Lampsilis teres</i>	5		12	11			3	1			8					21	3	16	1
<i>Ligumia subrostrata</i>	4		7	2				7	3		3	1	1	1		4	1	8	1
<i>Obliquaria reflexa</i>	2																		
<i>Plectomerus dombeyanus</i>	5		7	1	1		4	1				8	1	1		1			1
<i>Pleurobema rubrum</i>			1									2				3			
<i>Pyganodon grandis</i>							1												
<i>Quadrula apiculata</i>																1			
<i>Quadrula nodulata</i>	1																		
<i>Quadrula pustulosa</i>	1											1							
<i>Quadrula quadrula</i>	1			1								1							
<i>Toxolasma parvum</i>	31	3	38	46	3	26	7	3	7	16	25	10	29	3	14	15	10	5	1
<i>Toxolasma texasiensis</i>			31	37	1	23	2		2	12	4	9	22	1	4	6	8	1	

APPENDIX B

SOURCES OF INFORMATION ON HABITAT PREFERENCES FOR MISSISSIPPI
DELTA SPECIES ADDED TO UNIO.

Clarke, Arthur H., Jr., and Clifford O. Berg

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APPENDIX C
SENSITIVE SPECIES FOR UNIO

Table C.1 Complete list of all sensitive species in the UNIO program. Species are listed in alphabetical order.

			Sensitive for					
Taxon			Water-Body Type		Water Depth	Current Velocity	Substrate Composition	
<i>Actinonaias</i>	<i>ligamentina</i>	<i>gibba</i>				SW		
<i>Actinonaias</i>	<i>ligamentina</i>	<i>ligamentina</i>				SW	MO	
<i>Actinonaias</i>	<i>pectorosa</i>					SW		
<i>Alasmidonta</i>	<i>marginata</i>		LR	LC				
<i>Alasmidonta</i>	<i>viridis</i>					SL	ST	GS S
<i>Amblema</i>	<i>plicata</i>	<i>costata</i>	SR	LC				
<i>Amblema</i>	<i>plicata</i>	<i>peruviana</i>	LR			SW	MO	SM M
<i>Anodonta</i>	<i>suborbiculata</i>		LR	MR		ST		SM M
<i>Anodonta</i>	<i>imbecillis</i>					ST		
<i>Anodontoides</i>	<i>ferussacianus</i>					SL	ST	
<i>Arcidens</i>	<i>confragosus</i>		LR	MR		SL	ST	
<i>Arkansia</i>	<i>wheeleri</i>					SL	ST	SM M
<i>Cumberlandia</i>	<i>monodonta</i>		LR	MR		SL	ST	CG G
<i>Cyclonaias</i>	<i>tuberculata</i>		LR	MR				
<i>Cyprogenia</i>	<i>aberti</i>					MO	SL	
<i>Cyprogenia</i>	<i>stegaria</i>		LR	MR		SW		
<i>Dromus</i>	<i>dromas</i>	<i>caperatus</i>				SW		
<i>Dromus</i>	<i>dromas</i>	<i>dromas</i>	LR	MR		SW		
<i>Ellipsaria</i>	<i>lineolata</i>		LR			SW	MO	
<i>Elliptio</i>	<i>arca</i>					SL		
<i>Elliptio</i>	<i>crassidens</i>		LR			SW		
<i>Elliptio</i>	<i>dilatata</i>					SW		G GS
<i>Epioblasma</i>	<i>arcaeformis</i>		LR	MR				
<i>Epioblasma</i>	<i>brevidens</i>					SW		
<i>Epioblasma</i>	<i>capsaeformis</i>					SW		
<i>Epioblasma</i>	<i>flexuosa</i>		LR					
<i>Epioblasma</i>	<i>florentina</i>	<i>florentina</i>	LR	MR		SW	MO	
<i>Epioblasma</i>	<i>florentina</i>	<i>walkeri</i>				SW	MO	
<i>Epioblasma</i>	<i>lenior</i>		SR	LC		SW		
<i>Epioblasma</i>	<i>lewisii</i>		LR	MR				
<i>Epioblasma</i>	<i>obliquata</i>		LR	MR		SW		
<i>Epioblasma</i>	<i>penita</i>					SW	MO	
<i>Epioblasma</i>	<i>personata</i>		LR	MR				
<i>Epioblasma</i>	<i>propinqua</i>		LR	MR				
<i>Epioblasma</i>	<i>sampsonii</i>		LR	MR				
<i>Epioblasma</i>	<i>stewardsoni</i>		LR	MR				

Table C.1 (continued)

<i>Epioblasma</i>	<i>torulosa</i>		LR	MR		SW			
<i>Epioblasma</i>	<i>triquetra</i>		LR	MR		SW			
<i>Epioblasma</i>	<i>turgidula</i>		MR	SR					
<i>Fusconaia</i>	<i>barnesiana</i>					SW			
<i>Fusconaia</i>	<i>cor</i>					SW	MO		
<i>Fusconaia</i>	<i>cuneolus</i>					SW	MO		
<i>Fusconaia</i>	<i>ebena</i>		LR			SW			
<i>Fusconaia</i>	<i>flava</i>	<i>undata</i>	LR	MR		MO	SL	SM	M
<i>Fusconaia</i>	<i>ozarkensis</i>		MR	SR		SW	MO	G	GS
<i>Fusconaia</i>	<i>subrotunda</i>		LR			SW	MO		
<i>Glebula</i>	<i>rotundata</i>							SM	
<i>Hamiota</i>	<i>perovalis</i>					SW	MO		
<i>Lampsilis</i>	<i>abrupta</i>		LR			SW	MO	CG	G
<i>Lampsilis</i>	<i>cardium</i>		MR	SR		SW	MO		
<i>Lampsilis</i>	<i>fasciola</i>							G	GS
<i>Lampsilis</i>	<i>higginsii</i>		LR			SW		G	GS
<i>Lampsilis</i>	<i>hydiana</i>					SL			
<i>Lampsilis</i>	<i>ornata</i>					SL			
<i>Lampsilis</i>	<i>ovata</i>		LR	MR		SW	MO		
<i>Lampsilis</i>	<i>rafinesqueana</i>		SR	LC		MO		G	GS
<i>Lampsilis</i>	<i>siliquoidea</i>					SL	ST		
<i>Lampsilis</i>	<i>straminea</i>	<i>claibornensis</i>				MO	SL		
<i>Lampsilis</i>	<i>teres</i>	<i>anodontoides</i>	LR	MR					
<i>Lampsilis</i>	<i>teres</i>	<i>teres</i>				SL	ST	M	
<i>Lasmigona</i>	<i>complanata</i>	<i>complanata</i>				SL	ST	SM	M
<i>Lasmigona</i>	<i>compressa</i>		LC	SC		SL	ST		
<i>Lasmigona</i>	<i>costata</i>							CG	G
<i>Lasmigona</i>	<i>holstonia</i>		LC	SC					
<i>Lemiox</i>	<i>rimosus</i>					SW			
<i>Leptodea</i>	<i>fragilis</i>		LR			SL	ST		
<i>Leptodea</i>	<i>leptodon</i>		LR	MR	0 3			CG	G
<i>Lexingtonia</i>	<i>dolabelloides</i>					SW		G	GS
<i>Ligumia</i>	<i>recta</i>	<i>latissima</i>	LR	MR		SW			
<i>Ligumia</i>	<i>subrostrata</i>					SL	ST	M	
<i>Medionidus</i>	<i>conradicus</i>					SW	MO	G	GS
<i>Megaloniaias</i>	<i>nervosa</i>		LR			SL	ST	CG	G
<i>Obliquaria</i>	<i>reflexa</i>		LR	MR					
<i>Obovaria</i>	<i>jacksonia</i>		SR	LC		MO	SL	G	GS
<i>Obovaria</i>	<i>olivaria</i>		LR	MR		SW			
<i>Obovaria</i>	<i>retusa</i>		LR			SW			

Table C.1 (continued)

<i>Obovaria</i>	<i>subrotunda</i>	<i>subrotunda</i>	MR	SR			SW	MO		
<i>Pegias</i>	<i>fabula</i>				0	3				
<i>Plectomerus</i>	<i>dombeyanus</i>						MO	SL	SM	M
<i>Plethobasus</i>	<i>cicatricosus</i>		LR							
<i>Plethobasus</i>	<i>cooperianus</i>		LR						G	GS
<i>Plethobasus</i>	<i>cyphyus</i>		LR	MR			SW			
<i>Pleurobema</i>	<i>catillus</i>						SW			
<i>Pleurobema</i>	<i>coccineum</i>						MO	SL		
<i>Pleurobema</i>	<i>decisum</i>						MO	SL		
<i>Pleurobema</i>	<i>marshalli</i>		LR				SW	MO		
<i>Pleurobema</i>	<i>perovatum</i>						MO		GS	S
<i>Pleurobema</i>	<i>rubrum</i>		LR	MR			SW			
<i>Pleurobema</i>	<i>sintoxia</i>						MO	SL		
<i>Pleurobema</i>	<i>taitanum</i>						MO		G	GS
<i>Potamilus</i>	<i>alatus</i>								SM	M
<i>Potamilus</i>	<i>capax</i>		LR				MO	SL		
<i>Potamilus</i>	<i>ohiensis</i>		LR	MR			ST			
<i>Potamilus</i>	<i>purpuratus</i>						SL	ST	M	
<i>Ptychobranchus</i>	<i>fasciolaris</i>						SW			
<i>Ptychobranchus</i>	<i>subtentum</i>						SW		GS	S
<i>Pyganodon</i>	<i>grandis</i>	<i>corpulenta</i>	LR				SL	ST	SM	M
<i>Pyganodon</i>	<i>grandis</i>	<i>grandis</i>					ST		SM	M
<i>Quadrula</i>	<i>apiculata</i>		LR	MR			SW	MO	G	GS
<i>Quadrula</i>	<i>aspirata</i>						MO	SL		
<i>Quadrula</i>	<i>cylindrica</i>						SW			
<i>Quadrula</i>	<i>fragosa</i>		LR	MR						
<i>Quadrula</i>	<i>metanevra</i>						SW			
<i>Quadrula</i>	<i>nodulata</i>		LR						M	
<i>Quadrula</i>	<i>quadrula</i>		LR	MR						
<i>Quadrula</i>	<i>rumphiana</i>						SW	MO	G	GS
<i>Quadrula</i>	<i>sparsa</i>		MR	SR						
<i>Quadrula</i>	<i>stapes</i>		LR				SW	MO	CG	
<i>Quadrula</i>	<i>tuberosa</i>		LR	MR						
<i>Simpsonaias</i>	<i>ambigua</i>				0	3	SW			
<i>Strophitus</i>	<i>subvexus</i>						MO			
<i>Strophitus</i>	<i>undulatus</i>						MO	SL		
<i>Toxolasma</i>	<i>cylindrellus</i>		SR	LC						
<i>Toxolasma</i>	<i>lividus</i>		LC	SC	6		MO			
<i>Toxolasma</i>	<i>parvum</i>						SL	ST	M	
<i>Toxolasma</i>	<i>texasensis</i>				3	6	ST		M	

Table C.1 (continued)

<i>Uniomereus</i>	<i>declivis</i>	SR				
<i>Uniomereus</i>	<i>tetralasmus</i>		ST		M	
<i>Venustaconcha</i>	<i>ellipsiformis</i>		SW			
<i>Villosa</i>	<i>fabalis</i>		SW	MO		
<i>Villosa</i>	<i>lienosa</i>				SM	
<i>Villosa</i>	<i>iris</i>		MO	SL		
<i>Villosa</i>	<i>trabalis</i>		SW		G	GS
<i>Villosa</i>	<i>vanuxemensis</i>		SW	MO	G	GS

Habitat acronyms follow Warren (1991): Water-Body Type: LR is large river, MR is medium river, SR is small river, LC is large creek, SC is small creek, L is lake or pond. Current Velocity: SW is swift, MO is moderate, SL is slow, ST is standing. Substrate: CG is cobble-gravel, G is gravel, GS is gravel-sand, S is sand, SM is sand-mud, M is mud. Depths are reported in decimeters.